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EVALUATION OF CLIMATIC TEMPERATURE EFFICIENCY FOR THE RIPENING PROCESSES IN SWEETCORN

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INTRODUCTION

Green sweetcorn for table use or packing into cans is picked while the ripening processes are actively in progress. Since these processes greatly change the chemical composition of the corn, it is obvious that the ears must be picked as nearly as possible at the stage of ripening that will furnish the most desirable quality. There is some difference of opinion in regard to the chemical composition that gives the most desirable quality to sweetcorn, especially for packing into cans. Attention is usually focused upon sugar content, as sweetness is a desirable quality of sweetcorn and, morever, the flavor appears to be associated with the sugar content. This relationship may be merely a parallelism, but it is certainly true that corn acquires a decided flat taste after the sugar is reduced to low content either on the stalk or in storage. The foregoing statement does not necessarily apply to naturally low sugar content in certain varieties or to the same variety grown under different conditions.

The percentages of starch and crude fiber are claimed by some to be of equal if not of even greater importance than the sugar content. The percentage of starch must be sufficiently high to give body to the corn, while the amount of crude fiber must be kept as low as possible. Since the starch and crude fiber increase at the expense of the sugar, the most desirable stage for picking corn would seem to be a wise compromise between sugar content and other constituents.

The present paper deals with the chemical changes in sweetcorn during ripening and the effect of climatic temperature on rate of these changes. An attempt has also been made to evaluate the climatic temperature efficiency for these processes and to make the results of some practical value as a guide for picking corn in different localities and in different seasons in the same locality.

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In this study a distinction has been made between the ripening and the maturing processes. The corn is considered ripe when the growth of the kernels ceases and the chemical changes in the corn have nearly attained equilibrium positions—that is, it is ripe at the time after which the ratios of the various constituents change very slowly and very little. The maturing of corn consists essentially in the loss of water; therefore, the rate at which corn matures depends largely upon the climatic conditions which control evaporation.

CHANGES IN CHEMICAL COMPOSITION OF SWEETCORN DURING RIPENING

Stowell's evergreen corn grown from home-selected seed furnished the material for this study. For each experiment 50 ears representing as nearly as possible the same stage of ripening were carefully selected in the center of the field. These ears were numbered consecutively and designated as being in the premilk stage. The husks were not yet firm, and the silk was still green or red for about ½ inch beyond the tip of the husks. The remainder of the silk was, as a rule, brown but not dry. The kernels were inspected through a small longitudinal slit in the husks which was afterwards carefully closed and tightly held with a rubber band. The spikelets were still evident, the kernels small and spherical, and the exudate was opalescent or cloudy but not milky. This is about the earliest stage of ripening that will furnish sufficient kernel material from a single ear for sampling.

Samples for analyses were taken at 10 o'clock a. m. every other day during the ripening period. In order that the rate of change in chemical composition during each succeeding 48-hour period might be determined by comparing analyses from the same ear, as well as analyses from different ears, the following procedure was adopted: Samples of three rows of kernels each were removed from ears 1 and 2. The husks were then carefully brought back to place and held with rubber bands. After 48 hours a second pair of like samples was taken from the opposite sides of ears 1 and 2. At the same time the first pair of samples was removed from ears 3 and 4. At the end of the second 48-hour period the second samples were removed from ears 3 and 4 and the first samples from ears 5 and 6. This overlapping method of sampling was continued throughout the ripening period.

The treatment of the samples and the methods for the carbohydrate determinations have been described in a previous paper.[1] The methods for fat, crude fiber, and total nitrogen were essentially those of the Official Agricultural Chemists.[2]

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[1] APPLEMAN, Charles O., and ARTHUR, John M. CARBOHYDRATE METABOLISM IN GREEN SWEETCORN DURING STORAGE AT DIFFERENT TEMPERATURES. *In* Jour. Agr. Research, v. 17, no. 4, p. 137–152. 1919.

[2] ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS. OFFICIAL AND TENTATIVE METHODS OF ANALYSES. As compiled by the Committee on Revision of Methods. Revised to Nov. 1, 1919. 417 p., 18 fig. Washington, D. C. 1920. Bibliographies at ends of chapters.

Table I shows the changes in chemical composition of the solids in the corn during a typical ripening period. It was found that the rate of ripening was fairly uniform in all the ears selected for the experiment. Therefore the determinations from the four samples taken at each sampling period were averaged instead of the first and second samples from the same ears being compared, as was originally intended. Each percentage in the table, except the first set, represents an average of four determinations. The averages for the first date include the determinations from the first samples of ears 1 and 2. The averages for the succeeding dates include the determinations from the first samples of two ears and the second samples of the two ears that furnished the first pair of samples on the previous date. The removal of the first sample from an ear does not affect the rate of ripening in the kernels on the remaining half of the ear if the husks are closed tightly and held in place.

TABLE I.—*Changes in composition of sweetcorn during ripening*

[Calculated as percentages of dry weight]

Date.	Starch.	Cane sugar.	Reducing sugars.	Fat.	Crude fibre.	Total nitrogen.	Protein (total N×6.25).
Aug. 3	18.36	19.55	20.07	2.97	7.92	3.33	20.81
5	25.20	21.85	13.93	4.04	6.37	3.08	19.25
7	35.73	24.57	9.45	3.99	4.63	2.45	15.31
9	45.42	18.75	5.43	4.44	2.58	2.09	13.06
11	56.89	11.59	3.01	4.81	2.62	2.14	13.37
13	57.23	9.55	2.64	5.25	2.81	2.01	12.56
15	58.91	8.32	2.24	5.05	2.35	2.03	12.70
17	59.15	7.86	1.97	5.01	2.59	2.10	13.12
19	60.41	5.85	1.77	6.01	2.30	2.20	13.75

The chief changes in the percentage composition of the solids in the corn during ripening consist in the depletion of sugars and the increase in starch. In the very early stages the reducing sugars predominate but very rapidly decrease as ripening proceeds. The percentage of cane sugar increases until a maximum is reached and then decreases as the starch increases. The reducing sugars predominate at the stage of highest total sugar content; therefore this stage does not necessarily coincide with the stage of greatest sweetness, as the reducing sugars are not nearly as sweet as cane sugar. The highest content of the latter sugar is the stage of greatest sweetness. The changes in the percentage of fat, crude fiber, and total nitrogen occur during the very early stages of ripening. For the remainder of the ripening period these percentages remain fairly constant.

The formation and storage of starch is the chief process occurring in the kernels during ripening. This is the resultant of a number of complex processes in the plant, but it seems safe to conclude that the rate of starch synthesis in the kernels is the controlling factor for several supplementary processes in the ripening of the corn. For example, the rate

of movement of soluble carbohydrates from the stems and cob to the kernels and the rate of hydrolysis of cane sugar in the kernels are both controlled by the rate of starch formation. Most of the starch that is stored in the kernels during ripening is formed from carbohydrates already stored in the stem and cob when kernel formation begins. The intensity of respiration does not change the ratios of the different carbohydrate constituents in the ripe corn. The carbohydrate transformations being reversible, their final equilibrium positions are maintained.

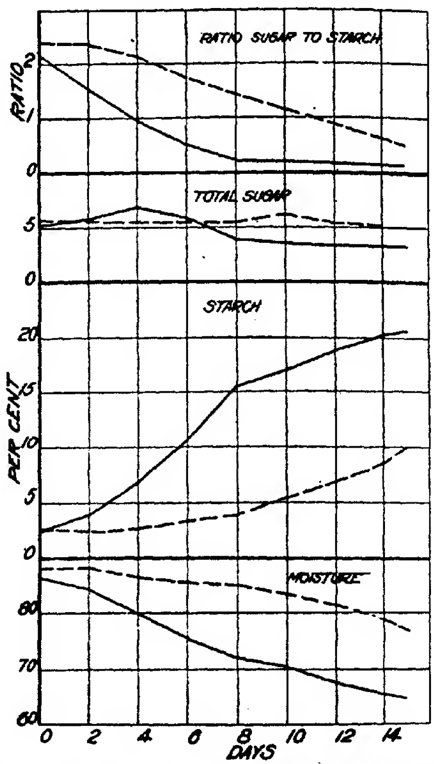

FIG. 1.—Comparison of early and late crops of sweetcorn in respect to changes in percentage composition in equal lengths of time. Early crop (Aug. 3 to 18) indicated by solid lines. Late crop (Sept. 20 to Oct. 5) indicated by broken lines.

EFFECT OF SEASON ON THE RATE OF RIPENING

Two crops of corn from the same source of seed were planted so that the first crop would ripen in August and the second in the cool autumn. In order to compare the ripening rates of the early and late crops, it was necessary to find a measure of the rate of ripening. The decrease in the

ratio of total sugar to starch was adopted for this purpose. Table II and figure 1 show the changes in percentage of moisture, total sugar and starch, and also the changing ratio of sugar to starch in equal times for the two seasons, starting with the same stage of ripening in both cases. By comparing these ratios it will be noted that the late crop required 15 days to reach the same stage of ripening as the early crop reached in 6 days. In other words, the rate of ripening was two and one-half times faster in the early crop than in the late crop. During this period of ripening the starch content in the early crop increased from about 2.5 per cent to 10.5 per cent, and in the late crop from about 2.7 per cent to 10 per cent. At the end of this ripening period the sugar to starch ratios were 0.556 and 0.500, respectively, and the chemical composition was such that it probably represented the best edible stage. By the nail test the corn was in the typical milk stage, but a subsequent paper will show that the chemical composition of the corn changes considerably during the so-called milk stage.

TABLE II.—*Comparison of early and late crops of sweetcorn in respect to changes in percentage composition in equal lengths of time*

Time from first examination.	Early crop.				Late crop.			
	Moisture.	Total sugars.	Starch.	Ratio of sugar to starch.	Moisture.	Total sugars.	Starch.	Ratio of sugar to starch.
Days.								
0	86.55	5.39	2.47	2.187	88.27	6.13	2.72	2.300
2	84.21	5.90	3.98	1.544	88.83	5.69	2.32	2.459
4	80.63	6.89	6.92	.868	86.97	5.78	2.86	2.168
6	75.89	6.09	10.95	[a] .556	85.56	5.53	3.39	1.747
8	72.05	4.21	15.90	.264	85.21	5.56	3.85	1.448
10	70.47	3.75	16.93	.219	83.80	6.30	5.48	1.164
12	67.78	3.50	18.98	.183	81.56	5.62	6.90	.879
14	65.51	3.55	20.42	.170	79.26	5.26	8.71	.673
15	64.98	3.02	20.94	.149	77.69	5.08	10.09	[b] .500

[a] Same stage of ripening as late crop on fifteenth day.
[b] Same stage of ripening as early crop on sixth day.

EVALUATION OF CLIMATE TEMPERATURE EFFICIENCY FOR THE RIPENING PROCESSES IN SWEETCORN

Since both the early and late crops of corn were grown from the same source of seed and on the same type of soil, the great difference in the rate of ripening must have been due to the different climatic conditions which prevailed during the ripening periods. Of the climatic conditions, temperature was the most important variable. The averages of the hourly mean temperatures for the ripening periods of the early and late crops were 83° and 65° F., respectively. The ripening processes being either chemical or dependent upon chemical processes, the prevailing temperatures for the two periods would be expected to have a very different

influence on the rate of ripening. But these ordinary temperature readings do not furnish a basis for a quantitative comparison of the temperature efficiency in reference to these processes.

Various methods have been proposed for interpreting the observed climatic temperatures in different localities and for different seasons in the same locality, with reference to plant growth. Three of these methods were applied to the fairly definite set of physico-chemical processes involved in the ripening of sweetcorn. The first method employed was one of direct temperature summation, similar to that described by MacDougal.[1]

The integration was performed, with a planimeter, upon thermograph records. The area between the 40° F. line and the pen tracing for each day of the two ripening periods was first measured. Then the mean temperature for each hour of a chosen day was computed from a thermograph record, and 40 was subtracted from each hourly temperature.[2] The sum of these results divided by the planimeter reading for the same day gave a factor by which the planimeter reading for any 24-hour period could be converted into hour-degree units of effective temperature. The total number of hour-degree units was computed for the 6- and 15-day ripening periods of the early and late crops, respectively. These units express both the intensity and duration aspects of the temperature factor. The adoption of the 40° as the starting point for the temperature summations was based upon the facts that carbohydrate changes are chiefly involved in ripening and that carbohydrate transformations in green corn during storage are extremely slow below this temperature.

The results of the direct temperature summations given in Table III show a slightly greater total number of hour-degree units of effective temperature in favor of the late crop. Stevens and Higgins[3] have shown that the temperature of green corn on the stalk in the shade is nearly that of the air, while in the sun it is often above that of the air. The period of ripening for the early crop heie considered was characterized by high temperature and clear days, while the ripening period of the late crop contained 2.5 times as many days, many of which were cloudy. Since the temperatuíe records from which the units of effective temperature were computed were taken in an instrument shelter, the sum of the hour-degree units for the early crop is probably a little less than actually required.

Livingston and Livingston,[4] realizing the need of some fundamental principle of physiology upon which to base the value of temperature

[1] MacDougal, D. T. THE TEMPERATURE OF THE SOIL. *In* Jour. N. Y. Bot. Garden. v. 3, no. 31, p. 125-131. fig. 19-21. 1902.

[2] The thermograph records were furnished by Dr. Earl S. Johnston of the Laboratory of Plant Pathology, Maryland Agricultural Experiment Station.

[3] Stevens, Neil E., and Higgins, C. H. TEMPERATURE IN RELATION TO QUALITY OF SWEETCORN. *In* Jour. Agr. Research, v. 17, no. 6, p. 275-284. 1 fig. 1919. Literature cited, p. 283-284.

[4] Livingston, Burton Edward, and Livingston, Grace Johnson. TEMPERATURE COEFFICIENTS IN PLANT GEOGRAPHY AND CLIMATOLOGY. *In* Bot. Gaz., v. 56, no. 5, p. 349-375. 3 fig. 1913.

summations, were the first to apply velocity coefficients to the study of effective climatic temperature conditions for plant growth. Upon the basic assumption that the growth rate is unity at 40° F. and that it doubles for each rise of 10° C. (18° F.), they deduced temperature efficiency values corresponding to temperatures, in whole numbers, from 40° to 99° F. These efficiency values are spoken of as exponential indices. Since the rate of the carbohydrate changes in corn after it is pulled has a temperature coefficient of about 2 for a range of temperature beyond the limits of the climatic temperature for either ripening period, and since the chief process during ripening is the conversion of sugar into starch, the exponential indices would be expected to furnish the best criteria of the temperature efficiency for the ripening processes in sweetcorn. In Table III are given the sums of the exponential indices corresponding to the daily mean temperatures of each ripening period under consideration, as well as the average daily index for each period. The average daily index for the early season is 2.5 times greater than that of the late season. If these indices furnish an approximate criterion of the temperature efficiency for ripening of sweetcorn, the ripening should have proceeded 2.5 times faster during the early ripening period than during the late ripening period. The experimental data show that this was actually the case; the late season required 15 days to carry the corn to the same stage of ripening that required only 6 days in the early season, a time ratio of 2.5.

More recently Livingston[1] has derived a new set of temperature indices which he terms physiological indices, since they are based upon Lehenbauer's actual measurements of the hourly rate of elongation of the shoots of seedling maize plants. For the sake of comparison these indices for the two ripening periods are also given in Table III, but it will be seen at once that they do not furnish even an approximate criterion of the temperature efficiency for the ripening processes in sweetcorn. This may be at least partially explained by the fact that, for the processes under consideration, the principle of Van't Hoff and Arrhenius seems to hold for rather a wide range of temperature, while in the elongation of maize shoots it holds only for a range of temperature from about 20° to 30° C.

[1] LIVINGSTON, Burton Edward. PHYSIOLOGICAL TEMPERATURE INDICES FOR THE STUDY OF PLANT GROWTH IN RELATION TO CLIMATE CONDITIONS. *In* Physiol. Researches, v. 1, no. 8, p. 399-420, 4 fig. 1916. Literature cited, p. 420.

TABLE III.—*Temperature indices in relation to ripening of sweetcorn*

Crop.	Time, between premilk and best edible milk stages.	Hour-degree units.	Exponential indices.		Physiological indices.	
			Sum.	Average.	Sum.	Average.
	Days.					
Early	6	6,425	31.81	5.3020	640	107.0
Late	15	7,393	32.22	2.1458	319	21.3

EXPONENTIAL INDICES AS A BASIS FOR AN APPROXIMATE PREDICTION OF THE RATE OF RIPENING IN SWEETCORN

Since the rate of ripening appears to be inversely proportional to the exponential indices, the proportions

$$6 : x : : y : 5.3020$$
$$2 : x : : y : 5.3020$$

furnish a basis for an approximate prediction of the number of days in different localities and for different seasons in the same locality required for corn to pass from the premilk stage to the best edible milk stage, and also the maximum number of days that the corn may be expected to remain in this condition. The first term of the first proportion is the number of days actually required for an early crop to pass from the premilk to the best edible stage, or from a starch content of about 2.4 per cent to one of 11 per cent. The first term of the second proportion is the maximum number of days that the corn of the early crop here considered remained in the best edible condition. The last term of the proportions is the average of the exponential indices corresponding to the daily mean temperatures for the 6-day period. By substituting for y in these proportions the average of the exponential indices derived from the normal daily mean temperatures for any season of any locality, the value of x in the first proportion gives the approximate number of days on the average that will be required for the corn to pass from the premilk to the best edible condition. The value of x in the second proportion gives the number of days that the corn may be expected to remain in this condition.

Table IV gives the values of x for the usual ripening seasons of four sweetcorn localities which show considerable variation in the normal mean temperature for the ripening periods. In this calculation, the normal mean temperatures calculated by Bigelow[1] were employed.

[1] BIGELOW, F. H. THE DAILY NORMAL TEMPERATURE AND DAILY NORMAL PRECIPITATION OF THE UNITED STATES. U. S. Dept. Agr. Weather Bur. Bul. R, 186 p. 1908.

TABLE IV.—*Comparison of the rates of sweetcorn ripening in different localities, based upon the exponential indices corresponding to the normal mean temperatures of the ripening seasons*

Locality.	Ripening season.	Time between pre-milk and best edible milk stage.	Length of time in best edible stage.
		Days.	*Days.*
Charleston, S. C.	June 17 to 31	7.0	2.5
	July 1 to 15	6.5	2.0
Baltimore, Md.	Aug. 1 to 15	8.0	2.5
	Aug. 16 to 31	8.5	3.0
	Sept. 1 to 15	9.5	3.0
	Sept. 16 to 30	11.5	4.0
	Oct. 1 to 15	14.0	5.0
New Haven, Conn.	Aug. 1 to 15	9.5	3.0
	Aug. 16 to 31	10.5	3.5
Portland, Me.	Sept. 1 to 15	14.0	4.5
	Sept. 16 to 30	16.0	5.5

The results given in Table IV are simply the average expectations, calculated for a 20-year period. If the mean temperature for a particular season deviates to any considerable extent from the normal mean, the rate of ripening for this season will be greater or less, depending upon the direction of the deviation, than that calculated from the normal mean temperature. In order to test the possible magnitude of deviation from the average expectation, the ripening rates were calculated for the highest and lowest mean August temperature at Baltimore from 1871–1918. These results together with those calculated from the normal mean August temperature for the same period are given in Table V. Data were not available from which to derive the exponential indices corresponding to the daily mean temperatures for the month as was done in calculating the data from normal mean temperatures given in Table III. However, the results suffice to indicate that for the most extreme seasons the number of days required for the two periods of ripening under consideration would not vary more than a day or two in either direction from the calculated average. If the particular season in question is unusually hot, one day would have to be subtracted from the average prediction. If, on the other hand, the season is unusually cool, one day would have to be added to the average expectation. This applies particularly to Maryland conditions.

In making the foregoing predictions it was assumed that most of the ears of a given crop will ripen at practically the same rate. This was found to be true in the experimental crops grown from home-selected seed. For canning purposes it is essential to use seed that will insure the maximum uniformity in ripening.

TABLE V.—*Rate of sweetcorn ripening during the month of August, calculated from Baltimore temperatures*

Temperature.	Exponential index.	Time between pre-milk and best edible stage.	Length of time in best edible stage.
		Days.	*Days.*
Normal mean, 75.3° F.	3.8480	8.3	2.7
Highest monthly mean, 1871–1918, 80.0° F.	4.6662	6.8	2.3
Lowest monthly mean, 1871–1918, 72.0° F.	3.4283	9.3	3.1

Stevens and Higgins state that the corn-picking season in Maryland has a much higher average temperature than the corresponding season in Maine, the difference being sufficient to cause considerably greater deterioration in picked corn during a given period.[1] They also derived the exponential and physiological indices corresponding to the daily normal temperatures for the corn-canning seasons of both localities. The means of these two sets of indices were both greater for Baltimore, Md., than for Portland, Me.; but they were unable to decide which method furnishes the best criteria of the relative rates of deterioration of picked corn in the two localities. The data presented in this paper and in a previous paper by Appleman and Arthur[2] lend support to the exponential indices as a good measure of the relative climatic temperature efficiency for the deterioration of picked corn in different localities.

The quality of canned corn may be influenced not only by the temperature at which the corn is handled but also by the effect of temperature on the rate of ripening. A slow rate of ripening gives a greater range in the number of days that the corn may be picked in good condition. Corn that ripens in very warm seasons, for example in the month of August in Maryland, requires very close attention lest the best stage for picking be allowed to pass. The data presented in this paper should furnish a more rational basis for picking green sweetcorn.

SUMMARY

Sweetcorn is considered ripe when the growth of the kernels ceases and the chemical changes in the corn have nearly attained equilibrium positions. The maturing of corn consists essentially in the loss of water.

The chief changes in percentage composition of corn during ripening consists in the depletion of sugars and the increase of starch.

In the very early stages of ripening the reducing sugars predominate; therefore the stage of highest total sugar content does not necessarily coincide with the stage of greatest sweetness.

[1] STEVENS, Neil E., and HIGGINS, C. H. OP. CIT.

[2] APPLEMAN, Charles O., and ARTHUR, John M. OP. CIT.

Calculated as percentages of dry weight, the changes in fat, crude fiber, and total nitrogen occur during the very early stages of ripening. For the remainder of the ripening period these percentages remain fairly constant.

The rate of starch synthesis in the kernels seems to be the controlling factor for several supplementary processes. The rate at which the ratio of total sugar to starch decreases is a good measure of the ripening rate and was employed for that purpose.

Temperature is the controlling factor for the rate of ripening in sweetcorn. Several temperature indices were employed to evaluate climatic temperature efficiency for the ripening processes. The exponential indices were found to furnish the best criteria of the temperature efficiency for sweetcorn ripening.

A late crop of corn required 15 days for the same period of ripening that required only 6 days for an early crop, a time ratio of 2.5. The averages of the daily exponential indices for the two seasons were practically in the same ratio. Therefore, the rate of ripening in sweetcorn, within a wide range of temperature, appears to adhere rather strictly to the Van't Hoff-Arrhenius principle.

The rate of ripening being inversely proportional to the exponential indices, a basis was furnished for an approximate prediction of the number of days required in different localities and at different seasons in the same locality for corn to pass from the beginning of kernel formation to the best edible stage, as well as the maximum number of days that the corn may be expected to remain in this condition.

SOME LEPIDOPTERA LIKELY TO BE CONFUSED WITH THE PINK BOLLWORM

By Carl Heinrich[1]

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INTRODUCTION

The purpose of the present paper is to define the characters which will distinguish the larva and pupa of the pink bollworm, *Pectinophora gossypiella* Saunders, from those of other Lepidoptera attacking cotton or related malvaceous plants and of still others feeding on plants other than malvaceous but frequently found in the neighborhood of cotton fields. A few (*Dicymolomia julianalis* Walker and *Crocidosema plebeiana* Zeller, for example) so closely resemble the pink bollworm in their habits and their larval stages that they are only to be distinguished by a careful examination of their structure. It is hoped that the present paper will make the differentiating characters clear and will enable entomological workers to distinguish the forms treated.

The field work upon which this paper is based was conducted throughout the area in southeastern Texas where the pink bollworm has been found to occur, as well as in Cameron County, at the southern extremity of the State. Special attention was devoted to discovering whether the pink bollworm was attacking plants other than cotton. Thousands of seed pods of okra and other malvaceous plants were examined. In one case, at Smiths Point, in Chambers County, all the seed pods of a plant related to cotton (*Hibiscus lasiocarpus*), growing in the immediate vicinity of a field where a heavy infestation by the pink bollworm had occurred during a previous year, were removed and given minute examination. Similar investigations were made with reference to other wild and cultivated malvaceous plants growing in or about fields where the

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[1] This study was conceived and arranged by Dr. W. D. Hunter, in charge of the Pink Bollworm Eradication, to aid the work of his inspectors. To the necessary preliminary field work the following entomologists were detailed by Dr. Hunter: H. C. Hanson, J. D. More, E. L. Diven, A. C. Johnson, and Carl Heinrich. For a short period Mr. Herbert Barber was also associated with the work. The material and notes on which the paper is based are all due to these workers. Especial mention should be made of Emerson Liscum Diven, who had a major part in the investigations and who lost his life in an aeroplane accident while scouting for cotton areas and who, had he lived, would have worked up the results as here given.

With the exception of Plate 107, all the drawings accompanying this paper were made under the writer's supervision by Mr. H. B. Bradford, of the Bureau of Entomology. Plate 107 (also originally by Mr. Bradford) is reproduced from Busck's article on the pink bollworm (*In* Jour. Agr. Research, vol. 9, no. 10, p. 343-370, 1917). The writer is especially indebted to Mr. Bradford for his painstaking and accurate drawings.

To Mr. Busck the writer is indebted for many helpful suggestions and both to him and to Dr. Dyar for verification of some of the identifications.

pink bollworm had been found. In no instance was the pink bollworm found in any plant other than cotton.

Thirty-eight species are considered here. Of these, six are described as new, and four, already described, are recorded for the first time from the United States. In each case the male genitalia of the type specimen of the new species are figured. The essential larval and pupal characters are referred to in the text as fully as possible, and purely descriptive matter is reduced to a minimum.

FAMILY GELECHIIDAE

PECTINOPHORA GOSSYPIELLA (SAUNDERS), THE PINK BOLLWORM

(PL. 101, A, B; 103, A; 105, C, E; 106, A; 107, A–D)

Depressaria gossypiella Saunders, 1843, *in* Trans. Ent. Soc. London, v. 3, pt. 4, p. 284–285.

Pectinophora gossypiella Busck, 1917, *in* Jour. Agr. Research, v. 9, no. 10, p. 343–370.

Inasmuch as the immature stages of the pink bollworm have been already fully described in an earlier number of this journal [1] it will be necessary here only to point out the structural characters which will serve to identify its larva and pupa and distinguish them from those of other Lepidoptera which, because of their habits, food plants, or general appearance, might be mistaken for *Pectinophora gossypiella*. There is no easy and ready-made method which will enable a layman to distinguish an insect and be certain of its identity. This applies with particular force to the pink bollworm. As Busck well states—

> Definite and final determination of *P. gossypiella* in any stage can be made only by the aid of a microscope

and he might have added, only by one reasonably experienced in insect determination and familiar with the characters used in classifying Lepidoptera. Nevertheless the pink bollworm has structural characters by which it can be determined and its identity established beyond the possibility of doubt. The specialist alone can pass upon these with certainty; but the average intelligent worker in the field can also use them, far enough at least to say what larvæ or pupæ commonly found in and about cotton fields can not be *P. gossypiella*.

The combination of the following characters distinguishes the larvæ of the pink bollworm:

Three setæ (III, IV, and V) triangularly grouped on the prespiracular shield of the prothorax (TI). (Pl. 103, A.)

Setæ IV and V closely approximate on the proleg-bearing abdominal segments (AIII). (Pl. 103, A.)

Setæ III above (not directly before) the spiracle on the eighth abdominal segment (AVIII).

[1] BUSCK, AUGUST. THE PINK BOLLWORM, PECTINOPHORA GOSSYPIELLA. *In* Jour. Agr. Research, v. 9, no. 10, p. 343–370, 7 fig., pl. 7–12. 1917. Literature cited, p. 366–370.

On the ninth abdominal segment (AIX) the paired dorsal setæ II not on a single pinaculum (chitinized plâte) and not appreciably closer together than the paired I on the dorsum of the eighth abdominal segment; seta I no nearer to III than to II; VI closely approximate to IV and V; group VII unisetose.

Prothoracic legs appreciably separated at their base. No anal fork on tenth abdominal segment. Crochets of abdominal prolegs uniordinal and arranged in a circle broken outwardly. (Pl. 106, A.)

On each side of the thoracic shield near Seta I^b a small crescent or reniform spot (Pl. 103, A) paler than the surrounding chitinized area.

On the epicranium the lateral seta (L^1) behind the level of P^1 and *remote* from A^3 (that is, farther from A^3 than A^3 is from A^2) and the anterior puncture (A^a) *lying between* setæ A^1 and A^2. (Pl. 101, A.)

Each of these characters is possessed by other lepidopterous larvæ, but their combination is peculiar to *Pectinophora gossypiella*. No other known larva that we have in this country possesses them all. I have not seen caterpillars of (*Gelechia*) *Pectinophora malvella* Zeller,[1] the only other known species of the genus Pectinophora, or of *Platyedra vilella* Zeller, which Meyrick considers congeneric with *Pectinophora gossypiella*.[2] These may have most or all of the structural characters here given, but as neither of them occurs outside of the Old World they do not concern us at present.

The setal characters are fully illustrated on Plates 101, 103, and 105. It will be noted that two slight changes have been made from the drawings published in Busck's paper. The numbering of abdominal setæ IV and V has been reversed to correspond with our present conception of the homologies of these setæ; and the lateral puncture (L^a) of the epicranium is shown directly posterior to rather than postero-ventrad of seta L^1. In Busck's figures[3] the puncture is much too low.

The pupa (Pl. 107, A–D) is evenly and densely clothed with a fine pubescence; moderately stout, with a short, hooked cremaster surrounded by 6 to 8 stout, hooked setæ but *without* dorsal spines or other armature; labial palpi absent; maxillary palpi long, extending four-fifths of the wing length; antennæ long but not quite reaching to tips of wings; vertex distinct but narrower than prothorax.

No other lepidopteron feeding on malvaceous plants in this country has such a pupa. The fine pubescence and short, hooked cremaster are easily discernible under a small hand lens and are enough to identify the pupa which, when once seen, is not likely to be confused with that of any other cotton-feeding species.

[1] After this paper had gone to the printer we received from the Abbé J. de Joannis of Paris a larva of *Pectinophora malvella*. The structural characters are the same as those of *Pectinophora gossypiella*.

[2] The Abbé Joannis also sent us a male moth of *Platyedra vilella*. A comparison of the genitalia of this and *Pectinophora gossypiella* does not support Meyrick's contention.

[3] BUSCK, August. OP. CIT., 1917, p. 348, fig. 2, B.

GELECHIA HIBISCELLA BUSCK

(PL. 93, C)

Gelechia hibiscella Busck, 1903, *in* Proc. U. S. Nat. Mus., v. 25, p. 869–871.
Gelechia hibiscella Busck, 1903, *in* Dyar, List North Amer. Lep., no. 5739.

This species was originally described from larvæ collected on *Hibiscus moscheutos* in the vicinity of Washington, D. C.

On the shores of Miller's Lake and Lake Charlotte in Chambers Co., Tex., we found the larvæ fairly abundant in early September (1918) on both *Hibiscus lasiocarpus* and *H. militaris* and also occasionally on *Kostelezkya* spp. During October of the same year adults were reared from these. The male genitalia compared with those of typical specimens from the type locality agree in all details. A figure of the elaborate and characteristic genitalia is given in Plate 93, C.

Gelechia hibiscella seems to be limited in food plant to Hibiscus and one or two other closely allied Malvaceae. We have never found it on cotton or okra, but there seems to be no reason why it should not thrive on these. The feeding habits vary somewhat according to the characters of the plant on which the larvæ feed. On the broader-leaved *Hibiscus moscheutos* around Washington and the similar *H. lasiocarpus* in Texas the larvæ feed chiefly on the leaves, rolling them up and partially biting through the stems before pupation so that the folded leaf is easily shaken to the ground by a slight wind. Within this roll they pupate. Occasionally the larvæ also attack the seed pods, but from the writer's observation this is rather rare in the broad-leaved species of Hibiscus. In the narrow-leaved *H. militaris* and in *Kostelezkya* spp., on the other hand, the habits are quite different. Here the larvæ feed chiefly in the flowers and seed pods, pupating in the withered flowers, and do not attack or use the leaves at all.

There is no possibility of confusing this species with *Pectinophora gossypiella*. The larvæ as well as adults of the two are very different. In *Gelechia hibiscella* the body of the larva from the beginning of the metathoracic segment to the caudal end is white, longitudinally marked with continuous, narrow, somewhat wavy, reddish brown stripes; one pair on the dorsum, lying between the paired setæ I; one subdorsal stripe on each side, above seta III, and a lateral stripe in the spiracular area. Except on the metathoracic and ninth abdominal segments none of the body tubercles are touched by the longitudinal stripes but lie between them on the white areas. The first two thoracic segments are reddish brown with the anterior portion of the mesothorax white above. The anal shield is yellow; the thoracic legs and prothoracic shield are black. The chitinizations about body tubercles moderate but conspicuous, black or blackish brown, rounded or oval, and sharply defined; crochets of prolegs uneven biordinal and in a complete circle, 32 to 36, brown; anal fork present, rather stout, 6- to 8-pronged; head yellow-brown,

more or less suffused and mottled with black; ocellar pigment black, continuous under all the ocelli. Full-grown larvæ 22 to 23 mm. long.

The only caterpillar treated in this paper which could easily be confused with this species is that of *Gelechia neotrophella* Heinrich. The latter, however, is at once distinguished by its 2-pronged anal fork and the fusing of the middorsal stripes on most of the abdominal segments.

GELECHIA BOSQUELLA CHAMBERS

Gelechia bosquella Chambers, 1878, *in* Bull. U. S. Geol. Surv. Terr., v. 4, p. 87.
Gelechia basquella Busck, 1903, *in* Dyar, List North Amer. Lep., no. 5729.

A single moth of this species was reared September 23, 1918, from *Cassia tora* infested by larvæ of *Platynota rostrana* Walker, collected at Turtle Bayou, Tex. This species is not a malvaceous feeder and is only mentioned here on account of the similarity of its larva to those of two other species treated in this paper, *Borkhausenia diveni* Heinrich and *Noctuelia rufofascialis* Stephens. It is very strikingly colored, the three thoracic segments being a bright wine-red while the rest of the body is green. The head, legs, thoracic shield, and body tubercles are black. The red coloring of the thoracic segments, however, is not continuous as in the two species just mentioned but is broken on the anterior portion of the meathtorax by a broad encircling band of the greenish body color. A detailed technical description of the larva is given by Dyar in Busck's revision of the American Gelechiidae.[1]

GELECHIA NEOTROPHELLA, N. SP.

(PL. 94, C-G; 105, H)

Gelechia neotrophella, n. sp.

Antennæ black. Palpi black, dusted with white. Face black, very slightly dusted with white. Head and thorax black, heavily dusted with white. Forewings black, marked with overlaid white scales; the white dustings over the black forming an oblique, basal grayish-white patch wider on dorsum than on costa, an obscure, rather broad median fascia consisting of a narrow, oblique median streak clouded with grayish before and behind, and a short white geminate costal dash at apical fourth; cilia smoky blackish fuscous. Hindwings and cilia pale smoky fuscous, somewhat shaded with black toward apex. Legs black, dusted and annulated with white. Male genitalia of type as figured (Pl. 94, C-G). Alar expanse 12 to 13 mm.

HABITAT.—Brownsville, Tex. (Diven and Heinrich).

FOOD PLANT.—*Mimosa berlandieri*. Larva a leaf-tier, spinning a tube of silk as it feeds and so binding the leaves together.

TYPE.—Cat. No. 23739, United States National Museum.

Described from one male type and two male and six female paratypes. Two generations were noted. From larvæ collected February 3, 1919, moths issued March 5, and from larvæ put in rearing early in May, 1919, adults emerged toward the end of the same month.

[1] BUSCK, August. A REVISION OF THE AMERICAN MOTHS OF THE FAMILY GELECHIIDAE, WITH DESCRIPTIONS OF NEW SPECIES. *In* Proc. U. S. Nat. Mus., v. 25, no. 1304, p. 864-865. 1903.

The larva is yellowish white, longitudinally striped with wine-red; one rather broad middorsal stripe dividing into two thin parallel stripes from the second abdominal segment forward; one moderately broad subdorsal and one lateral stripe extending from hind margin of prothorax and fusing on the ninth abdominal segment and forming on the tenth a dark border around the outer edge of the anal shield; in the area of seta VI a similar narrow sublateral stripe; head and thoracic shield pale yellow; crochets of prolegs 28 to 34, biordinal and arranged in a complete circle; anal prolegs with a conspicuous blackish red chitinized spot on caudal side; anal fork rather large, 2-pronged; full-grown larva 8 to 8.5 mm. long.

The species is close to and strikingly resembles *Gelechia trophella* Busck, from which, however, it is easily distinguished by the male genitalia. The structural differences are shown in Plate 93, A and B, and in Plate 94, C–G.

The larva is not in any way to be confused with the pink bollworm, from which it differs strikingly in superficial appearance. It resembles somewhat the larva of *Gelechia hibiscella* Busck but is separable from that species by food plant and structure. In *G. neotrophella* the anal fork is 2-pronged, while in *G. hibiscella* it has from 6 to 8 distinct prongs. In the latter, also, the dorsal stripes are nowhere fused.

TELPHUSA MARIONA, N. SP.

(PL. 94, A, B; 105, F; 109, G)

Telphusa mariona, n. sp.

Antennæ black. Palpi cream-color, shading to white on upper side of second joint; apical half of third joint and upper side of basal joint black. Face white. Head and thorax cream-yellow. Forewings glossy black with two conspicuous cream-colored spots; one, a short triangular dash on outer third of costa; the other, an irregular spot of about the same size on dorsum just beyond middle; in some specimens two or three minute and obscure patches of white or cream-colored scales along termen; cilia blackish. Hindwings and cilia smoky fuscous. Legs black, ringed at outer margins of the joints with cream-yellow or white. Male genitalia of type as figured (Pl. 94, A, B). Alar expanse 9 to 11 mm.

HABITAT.—Brownsville, Tex. (J. D. More and H. C. Hanson).

FOOD PLANT.—*Abutilon incanum*. Larva a leaf-folder. Also taken on *Abutilon berlandieri*, *Malvastrum* sp., *Wissadula* sp., and *Sida* sp.

TYPE.—Cat. No. 23740, United States National Museum.

Described from male type and 25 male and female paratypes reared from larvæ collected in late March and early April, 1919, on *Abutilon incanum*. Moths issued from middle of April to middle of May, 1919.

Larva, full-grown, 6.5 to 7 mm. long; slender. Body yellowish white with a subdorsal and a lateral longitudinal row of large red blotches and a longitudinal row of smaller red spots on the level of seta VI and just anterior to that seta on each segment; on the eighth abdominal segment the paired subdorsal spots are fused and on abdominal segment 9 the

subdorsal and lateral spots are also fused; legs pale yellow; crochets light brown, 18 to 20 in a complete circle, unevenly biordinal; thoracic shield divided by a thin median longitudinal pale line, yellow with a broad shading of fuscous on the lateral extremities and a smaller fuscous patch at the center of the anterior dorsal margin; anal shield yellow laterally shaded with fuscous; other chitinized areas smoky fuscous, tubercles moderately chitinized; hairs moderately long, slender, yellowish. Head light yellow with a narrow black shading at posterior lateral incision of hind margin and a similar black dash on ventral margin of epicranium adjacent to triangular plate of hypostoma; ocellar pigment black, continuous under all the ocelli.

The larva is very similar in superficial appearance to the scavenger worm (*Pyroderces rileyi* Wlsm.). It differs most strikingly in the arrangement of the red markings, which are in spots or blotches rather than in continuous bands, and in the possession of a well-developed anal fork (Pl. 105, F) entirely lacking in *P. rileyi* and the pink bollworm.

The pupa is easily distinguished from those of the other Lepidoptera treated in this paper by the peculiarly scalloped and fringed posterior margin of its eighth abdominal segment. (Pl. 109, G.)

ISOPHRICTIS SIMILIELLA (CHAMBERS)[1]

(PL. 95, A; 102, F)

Gelechia similiella Chambers, 1872, *in* Canad. Ent., v. 4, p. 193.
Paltodora similiella Busck, 1903, *in* Dyar, List North Amer. Lep., no. 5548.

In the dead flower heads of *Rudbeckia* sp. (commonly called "nigger heads" in many parts of Texas) there are two species of lepidopterous larvæ which many nonentomologists have confused with *Pectinophora gossypiella.* One of these when mature is about the same size as and superficially like a full-grown pink bollworm. It is an olethreutid, however, and as such is easily distinguished by the setal arrangement of the ninth segment which readily separates the two families Gelechiidae and Olethreutidae. In the former the paired setæ II on the dorsum of the ninth segment are no closer together than the paired setæ I on the dorsum of abdominal segment 8 (Pl. 105, C) and I is as near II as it is III on the ninth abdominal segment. In the Olethreutidae, on the other hand, the paired II on the dorsum of the ninth abdominal segment are on a single chitinization and *closer together* than the paired I on the eighth abdominal segment. Also I and III are closely approximate (Pl. 105, B). We have not succeeded in rearing the moth, so specific determination can not be given. The family position of the larva, however, is certain.

[1] The genus Isophrictis has been erected by Meyrick for those species formerly listed under the genus Paltodora Meyrick having the second joint of the labial palpi clothed beneath with long rough spreading hairs and having veins 7 and 8 of forewings out of 6. It replaces Paltodora for the North American species. (MEYRICK, E. ON THE GENUS PALTODORA. *In* Ent. Mo. Mag., v. 53, no. 636 [s. 3, v. 3, no. 29], p. 113. 1917.)

The other Rudbeckia feeder (*Isophrictis similiella* Chambers) belongs to the same family as the pink bollworm and is much more abundant and less local than the olethreutid. It feeds on the seeds of a number of Compositae and is frequently found in sunflower heads. The larva when mature often has a pinkish tinge and somewhat resembles an immature pink bollworm except for its shape, which is distinctly spindle-like, sharply tapering at both ends and decidedly stout for its length (1.5 to 2 mm. wide by 5 mm. long in full-grown specimens). The arrangement of the setæ of the anterior group on the epicranium is also characteristic; A^1, A^2, and A^3 are crowded very close together on the anterior dorsal part of the head and L^1, while remote from A^3 as in most Gelechiidae, is well forward near the ocelli. (Pl. 102, F.)

The pupa shows under the microscope a slight pubescence similar to that of *Pectinophora gossypiella* but this is *limited to the head alone*. Otherwise, except for the normal setæ and a sharp, thorn-like, *dorsally projecting* cremaster, the pupa is smooth. It is short and moderately stout (1.5 mm. broad by 5.5 to 6 mm. long) with the wing cases reaching nearly to and the metathoracic legs extending a trifle beyond the tip of the abdomen.

Several moths of this species were reared from larvæ collected at various points in Chambers County and in the neighborhood of Galveston and Houston. Larvæ were collected in late August and early September, 1918, and adults issued from these from the middle to the end of September the same year. Other larvæ, taken in October of 1918, produced moths the following May, passing the winter as pupæ within the dried flower heads.

The male genitalia of the moth are figured in Plate 95, A.

FAMILY OECOPHORIDAE

BORKHAUSENIA DIVENI, N. SP.

(PL. 96, C–F)

Borkhausenia diveni, n. sp.

Antennæ white, faintly annulated with fuscous above. Palpi blackish fuscous, broadly banded at base and apex of third joint with white; inner sides somewhat dusted with white scales. Face white. Head white with a slight suffusion of fuscous at vertex. Thorax white, heavily dusted with blackish fuscous; tegulæ white, basal half blackish fuscous. Forewings white, suffused and mottled with pale brown and black scales, the brown suffusion obscuring most of the ground color at the base and beyond the middle of the wing; an irregular black spot at base of costa; a similar black spot on lower vein of cell close to base; above and below it two smaller black spots; at middle of wing a straight, rather broad, vertical fascia of blackish brown scales inwardly margined by a distinct line of the white ground color; in the middle of this fascia a round spot of distinctly paler brown scales with the black scales edging it slightly raised; on costa just beyond median fascia a poorly defined triangular patch of brown and blackish scales; a small black dot at upper outer angle of cell and several small obscure dark spots near tornus; cilia dirty white. Hindwings and cilia grayish

fuscous. Legs fuscous on outer sides; banded with white on middle of tibiæ and at ends of joints; white on inner sides. Male genitalia of type figured (Pl. 96, C–F). Alar expanse 12 to 13 mm.

HABITAT.—Brownsville, Tex. (E. L. Diven).

FOOD PLANT.—*Lantana horrida.* "Larvæ making a narrow blotch mine at the edge of the leaf and curling the edge near base, pupating within the mine" (Diven note).

TYPE.—Cat. No. 23741, United States National Museum.

Described from male type and one male and three female paratypes reared from larvæ collected April 22, 1919. Moths issued April 27 to May 5, 1919. Named in honor of the late Emerson Liscum Diven.

The larva when full-grown is 7.5 to 9 mm. long; white, with the thoracic segments and the anterior portion of the first abdominal segment a brilliant wine-red; in fully fed specimens there is often a pinkish suffusion on the dorsum of the abdominal segments; thoracic shield yellow, posteriorly and laterally edged with dark brown; anal shield pale yellow; other chitinized portions of thoracic segments dark brown; thoracic legs blackish brown, paler on inner sides; body tubercles deep brown, minute; setæ pale, slender, moderately long; crochets of prolegs dark brown, 24 to 26, biordinal and in a circle broken outwardly; spiracles pale yellow, small, round, inconspicuous; no anal fork; head pale yellow with a dark brown band on each side, extending from the ocelli to the lateral incision of the hind margin; ocellar pigment black, continuous under the ocelli.

The pupa is rather stout and short, 1.5 to 2 mm. wide by 4.5 to 5 mm. long; pale yellow-brown; smooth; caudal end rounded; cremaster absent; wings and antennæ extending to anterior margin of sixth abdominal segment; labial palpi clearly defined but small, *not* extending to proximolateral angles of maxillæ; between genital and anal openings a divided, blackish, chitinized rise, without spines, hairs, or other armature.

This species is easily distinguished from the other American forms in the genus by the straight median fascia. I have placed it in Borkhausenia advisedly, although strictly speaking it does not belong there. In any further revision of the Oecophoridae, *Borkhausenia divini* with *B. conia* Wlsm., *B. fasciata* Wlsm., *B. episcia* Wlsm., and probably *B. orites* Wlsm., will have to be placed in a new genus. While agreeing with the type of Borkhausenia (*B. minutella* L.) on venational characters, they differ markedly in genitalia. In *B. minutella* (Pl. 96, A, B) the harpes are typically oecophorid and laterally placed, the uncus present though small, the eighth abdominal segment simple, and the entire apparatus symmetrical. In *B. diveni* and its allies, on the other hand (Pl. 95–97), the eighth abdominal segment is distinctly modified, the uncus is absent, the harpes more ventrally placed, and the genital apparatus consistently asymmetrical. The characters of their genitalia are those of the genus Triclonella Busck, from which the species are separable on venation, *B. diveni* and its allies having 5 of the hind wing distinctly separate at base from the stalk of 3 and 4. The presence of a few raised scales on

the forewing would seem to throw *B. diveni* into Meyrick's genus Erysiptila. The latter, however, is again distinct on characters of genitalia on which it will have to be retained and recharacterized, as the raised scale character does not seem to hold. It is possessed by *B. diveni* but not by the other closely allied species (*B. conia*, *B. fasciata*, etc.). The genus Erysiptila, while similar to these in some genitalic characters (for example, the peculiar development of fused and armed soci and gnathus) and thus separable from the genus Borkhausenia, has the organs symmetrical throughout and the harpes laterally rather than ventrally placed. Of the North American species now listed under the genus Borkhausenia only three (*B. pseudospretella* Staint., *B. haydenella* Chambers, and *B. ascriptella* Busck) agree with the type species on all characters. For the present, however, *B. diveni* and its allies may be retained in that genus. Until the entire family can be revised along lines suggested by the development of genitalic structures there is nothing to be gained by erecting a single genus on these characters.

FAMILY STENOMIDAE

AEDEMOSES HESSITANS WALSINGHAM [1]

(PL. 95, B, C; 104, D)

Aedemoses hæsitans Walsingham, 1912, *in* Biol. Centr.-Amer., Lep. Heter., v. 4, p. 154.

Eighteen specimens (males and females) of a moth which Mr. Busck has determined as this species were reared by Diven from larvæ which he had collected on "Mexican ebony" (*Siderocarpus flexicaulis*) at Brownsville, Tex. The genus and species were described by Walsingham from a unique female without hind legs, collected at Presidio Durango, Mexico, and have not since been recorded. The present rearing, therefore, adds another to our list of United States species. There can be no doubt of the identification, as Busck has seen and is familiar with the Walsingham type and our reared examples agree in all details with the description.

The larva is a leaf-tier, binding together several leaves and feeding within the tie, eating first the epidermis and later all but the veins of the leaves. It pupates within the tie, the pupa being naked and attached at its caudal end by a strand of silk to one of the leaves.

The larva is a typical stenomid, slightly flattened and with seta III *antero-dorsad* of and close to the spiracle on abdominal segments 1 to 7 (Pl. 104, D); body white with four pale purplish brown longitudinal stripes, one subdorsal pair just below the level of setæ I and II, and a dorso-lateral one just above the level of setæ III; thoracic and anal shields pale yellow; thoracic legs pale yellow, lightly shaded with brown;

[1] Meyrick sunk the genus Aedemoses Walsingham as a synonym of the genus Stenoma Zeller, but on insufficient grounds, as he disregards its very distinct venational structure in favor of general appearances. (MEYRICK, E. EXOTIC MICROLEPIDOPTERA, v. 1, pt. 13, p. 411. 1915.)

body tubercles inconspicuous, chitinized areas about them unpigmented except around setæ II^a and II^b on mesothorax and metathorax where they are pale brown; body hairs whitish yellow, rather long; abdominal crochets yellow, 40 to 44, unevenly biordinal and in a complete circle; anal fork absent; head pale yellow, the more heavily chitinized parts of trophi lighter brown; ocellar pigment black, continuous under the ocelli; length, full grown, 7 to 7.5 mm.

The pupa is the typical short, squatty stenomid form; smooth, without armature or processes of any kind except the very short, inconspicuous primary setæ and a pair of minute spines on the anal rise; seta III on abdominal segments well forward of the spiracle; spiracles distinct and rather large, very slightly produced; wings, antennæ, and metathoracic legs extending to anterior margin of fifth abdominal segment; antero-ventral margins of fifth abdominal segment curved around the edge of the wing tips; labial palpi very small, not reaching to proximo-lateral angles of maxillæ; eighth, ninth, and tenth abdominal segments considerably reduced and sharply tapering; prothorax broad, nearly one-third the breadth of mesothorax; proleg scars distinct; length 4 to 4.5 mm; width 1.5 to 2 mm.

Immature larvæ were collected by Diven in late January, 1919, and feeding larvæ as late as April 1, 1919; from the latter, moths issued from April 17 to 26 of the same year.

The male genitalia of the moth are figured in Plate 95, B, C.

FAMILY BLASTOBASIDAE

ZENODOCHIUM CITRICOLELLA (CHAMBERS)

(PL. 98, A–C; 102; 104, C; 105, I)

Blastobasis citricolella Chambers, 1880, *in* Rept. U. S. Dept. Agr. 1879, p. 206–207.
Blastobasis citriella Chambers, 1880, *in* Rept. U. S. Dept. Agr. 1879, p. 245.
Zenodochium citricolella Dietz, 1910, *in* Trans. Amer. Ent. Soc., v. 36, p. 11–12.

Feeding in dry okra pods, in the seed pods of Hibiscus, and in old or diseased cotton bolls we often found associated with *Pyroderces rileyi* a dirty brownish larva with a glistening black head and thorax, spinning a thin web in the seed pods within which it fed and pupated. A number were collected at various places in Chambers County (Smith Point, Point Bolivar, and South Bayou) and from these were reared a number of adults agreeing in genitalic and other characters with authentic reared specimens of *Zenodochium citricolella* Chambers in the United States National Museum. The species is a scavenger and probably a very general feeder, as it was originally recorded from dried oranges and is to be found in almost any dry or diseased malvaceous seed pod.

Figures of the male genitalia of the moth are given in Plate 98, A–C.

The larva is easily distinguished from *Pyroderces rileyi* and the other lepidopterous cotton feeders by the structural characters shown on Plates 102, 104, and 105. The most striking features are the oval chitinized plate on the submentum, the nearly complete fuscous circle surrounding the chitinization of tubercle III on abdominal segments 1 to 7, and the typical blastobasid arrangement of the prothoracic legs (Pl. 105, I), set very close together with the coxal lobes touching each other.

The species probably has several generations a year. Larvæ collected in August, 1918, produced moths in that month and throughout September. Others collected during November and December produced moths the following April.

HOLCOCERA OCHROCEPHALA DIETZ

(PL. 98, D–F)

Holcocera ochrocephala Dietz, 1910, *in* Trans. Amer. Entomol. Soc., v. 36, p. 31–32.

A large series of moths were reared during February and March, 1919, from larvæ collected December, 1918, in imperfectly opened and weevil-infested cotton bolls at Brownsville, Tex. They agree with the description and the single female paratype of Dietz's species in the United States National Museum, and I have no hesitation in so determining them. The larval habits are the same as those of *Zenodochium citricolella*. There probably has been some confusing of our material, as all the larvæ we have associated with the *H. ochrocephala* adults are identical with those of *Z. citricolella*. Probably, since the two species work together in the same way and are superficially alike, the larvæ of one species was preserved and that of the other reared. It is extremely unlikely that there should be two blastobasids in different genera without a single structural difference in their larvæ.

The male genitalia of the moth are figured in Plate 98, D–F.

HOLCOCERA CONFAMULELLA, N. SP.

(PL. 99, C)

Holcocera confamulella, n. sp.

Antennæ deeply excised above basal joint and with truncate scale tuft; very **weakly ciliate. Palpi grayish ochreous, dusted with fuscous** on outer sides. Face **grayish ochreous, vertically banded with fuscous. Head and thorax** grayish white **mixed and suffused with fuscous scales. Forewings grayish** white, suffused and **mottled with fuscous, the fuscous scaling giving the outer** two-thirds of the wing a **distinctly gray-brown appearance, darkening into an ill-defined**, outwardly angulate **antemedial fascia bordering a grayish basal patch and forming** an irregular, broken, **and obscure vertical fascia beyond the middle; along the termen** a few barely dis**tinguishable fuscous spots; cilia grayish white. Hindwings very** narrow, pale smoky **fuscous; cilia paler, tinged with ochreous. Legs whitish ochreous** on inner sides; **the outer sides fuscous, spotted with white on tibiæ and ringed** with white or whitish **ochreous at ends of joints. Male genitalia of type figured** (Pl. 99, C). Alar expanse **14 to 15 mm.**

HABITAT.—Brownsville, Tex. (More, Barber, Heinrich).
FOOD PLANT.—Fruits of Crataegus.
TYPE.—Cat. No. 23742, United States National Museum.

This species is very close to *Holcocera modestella* Clemens, to which it would run in Dietz's tables.[1] It may eventually prove to be that species, but in the absence of an authentic male of *H. modestella* from the type locality it is better to risk a possible synonym than to make a doubtful determination. I have seen no specimens of Clemens's species. The male genitalia here figured fix the concept of *H. confamulella* and enable its ready identification.

Five moths (male type and four male and female paratypes) were reared April 10 to 21, 1919, from fruits of Crataegus rather heavily infested by larvæ of *Crocidosema plebeiana* Zeller. The larvæ of *Holcocera confamulella* were not noted.

FAMILY ETHMIIDAE

ETHMIA DELLIELLA (FERNALD)

Psecadia delliella Fernald, 1891, *in* Canad. Ent., v. 23, p. 29.
Babaiaxa delliella Busck, 1903, *in* Dyar, List North Amer. Lep., no. 5935.
Ethmia delliella Barnes and McDunnough, 1917, Check List Lep. Bor. Amer., no. 6645.

One moth reared April 30, 1919, from *Wissadula lozani* heavily infested by a stem-boring aegeriid (*Zenodoxus palmi* Neumoegen). Material collected at Brownsville, Tex., by E. L. Diven, March 28, 1919. Larva and habits not noted.

ETHMIA BITTENELLA (BUSCK)

Tamarrha bittenella Busck, 1906, *in* Proc. U. S. Nat. Mus., v. 30, p. 730.
Ethmia bittenella Meyrick, 1914, Lep. Cat., pars. 19, p. 28.

Two pupæ collected by Diven in galleries in stems of *Wissadula lozani*, Brownsville, Tex., April 1, 1919. Moth issued April 9, 1919.

The larvæ were not noted. The caterpillars of this family are, however, to be distinguished from the others having three setæ on the prespiracular shield of prothorax and IV and V of abdomen approximate by the presence of one or more secondary hairs on the body, usually on the abdominal segments in the region of the prolegs. The prolegs themselves are long and slender as in the Pterophoridae. On abdominal segment 9, seta I is higher than II.

[1] DIETZ, Wm. G. REVISION OF THE BLASTOBASIDAE OF NORTH AMERICA. *In* Trans. Amer. Ent. Soc., v. 36, no. 1, p. 24-33. 1910.

FAMILY COSMOPTERYGIDAE

PYRODERCES RILEYI (WALSINGHAM)

(PL. 102, A, B; 103, C; 105, D; 106, C; 107, E, F)

Batrachedra rileyi Walsingham, 1882, *in* Trans. Amer. Ent. Soc., v. 10, p. 198–199.
Batrachedra rileyi Dyar, 1903, List North Amer. Lep., no. 6059.
Pyroderces rileyi Busck, 1917, *in* Jour. Agr. Res., v. 9, no. 10, p. 362–366, 370.

The larva of this common scavenger is frequently mistaken for the pink bollworm. It is, however, very readily distinguished from it and similar pink-banded larvæ of the gelechioid and other groups.

Since a complete description of adult, larva, and pupa is given in Busck's article on the pink bollworm,[1] it will suffice here to call attention to the diagnostic characters of the immature stages.

For the larva these are:

Three setæ (III, IV, and V) triangularly grouped on prespiracular shield of prothorax; prothoracic II[a] higher than I[a]; IV and V on proleg-bearing abdominal segments approximate; III on eighth abdominal segment *anterior to the spiracle;* paired dorsal setæ (II) on the ninth abdominal segment *not on a single chitinization*, but closer together than paired I on eighth abdominal segment (Pl. 105, D); *I and III approximate on ninth abdominal segment* (as in the Olethreutidae); IV and V approximate, with VI well separated from them on ninth abdominal segment; crochets of prolegs uniordinal and in a complete circle; anal fork absent; pink bandings on anterior and posterior margins (not in the middle) of the segments.

The sum total of these characters is possessed by no other caterpillar to be found on cotton.

The pupa (Pl. 107, E, F) may be distinguished by the following characters:

Pointed wing cases reaching to posterior margin of the sixth abdominal segment; antennæ reaching to tips of wings; maxillary palpi small and not reaching proximo-lateral angles of maxillae; vertex wider than prothorax; abdomen tapering, bluntly rounded, smooth except for primary hairs and a cluster of strong hooked setæ at posterior end and around anal opening; cremaster absent; no labial palpi or exposed metathoracic legs.

The drawings (Pl. 102, 103, 105–107) show the distinguishing structural characters of larva and pupa. It will be noted that a correction has been made in Busck's figure of the setal map of the ninth abdominal segment of the larva which omitted one of the ventral setæ. The setal arrangement of the ninth abdominal segment with all setæ in a row, I approximate to III and VI well-separated from IV and V, can not be

[1] BUSCK, August. OP. CIT. 1917, p. 362–366.

considered a family character. It serves, however, to separate *Pyroderces rileyi* from the gelechioid forms which it otherwise resembles.

FAMILY TORTRICIDAE

PLATYNOTA ROSTRANA (WALKER)

(PL. 104, A; 105, A)

Teras rostrana Walker, 1863, *in* List Lep. Brit. Mus., pt. 28, p. 290.
Platynota rostrana Dyar, 1903, List North Amer. Lep., no. 5383.

This species and the following two are rather general feeders and are frequently found on cotton and other Malvaceae. We have reared moths of *Platynota rostrana* from cotton, okra (*Hibiscus esculentus*), *Malvaviscus drummondii*, *Bastardia viscosa*, *Amaranthus* spp., and *Cassia tora*, collected at Brownsville and several localities in Chambers County. The species is normally a leaf-feeder, tying the terminal leaves and pupating within the tie. We have, however, also found it occasionally feeding on the flower buds of okra and on one occasion (Dec. 31, 1918) Diven took three larvæ at Brownsville in dry cotton bolls, feeding on the lint. They pupated in the loose lint, and moths issued February 7 and March 3, 1919. In the Chambers County localities larvæ were collected during late August and early September, 1918, which produced moths late in September and early in October of the same year. There are at least two and probably three or more generations a year in Texas.

The larva is not likely to be confused with the pink bollworm. It is easily separable on the setal characters figured on Plates 104 and 105. The arrangement of the pared dorsal setæ (II) on the ninth abdominal segment (that is, *on a single chitinization* and considerably closer together than any dorsal pair on the eighth abdominal segment) (Pl. 105, A), coupled with the normal micro characters of three setæ on the prespiracular shield of prothorax, and a close approximation of IV and V on the proleg-bearing abdominal segments, distinguishes the families of the Tortricoidea. In Tortricidae proper (to which this and the two following species belong) seta I on the ninth abdominal segment is much as in the Gelechiidae (that is, rather well separated from III and often as near to II as to III) (Pl. 105, A). In the families Olethreutidae and Phaloniidae, on the other hand, I and III are approximate and very often on the same chitinization.

The pupa is typically tortricoid, with wings short and broad at the tip (not tapering) and having the abdominal segments armed dorsally with a double row of strong spines, those of the anterior rows larger and somewhat hooked (compare Pl. 108, D). It is distinguished from that of the common olethreutid malvaceous feeder (*Crocidosema plebeiana* Zell.) by the presence of a well-developed, bluntly rounded cremaster entirely lacking in the latter.

PLATYNOTA FLAVEDANA CLEMENS

Platynota flavedana Clemens, 1861, *in* Proc. Acad. Nat. Sci. Phila., 1860, p. 348.
Platynota flavedana Dyar, 1903, List North Amer. Lep., no. 5382.

One specimen reared by Diven (May 23, 1919) from cotton leaves collected at Brownsville, Tex., May 7, 1919.

The larva was not noted.

The pupa is strikingly like that of *Platynota rostrana* Walker.

AMORBIA EMIGRATELLA BUSCK

(PL. 109, F)

Amorbia emigratella Busck, 1910, *in* Proc. Ent. Soc. Washington, v. 11, p. 201–202.
Amorbia emigratella Walsingham, 1913, *in* Biol. Centr.-Amer., Lep. Heter., v. 4, p. 219.

Two moths reared from cotton May 19 and 24, 1919 (E. L. Diven) in same material infested by *Platynota flavedana*, collected at Brownsville, Tex., May 7, 1919. The pupa has a conspicuous mid-dorsal, cuplike, circular invagination near the anterior margins of the first seven abdominal segments, the anterior dorsal margins themselves being strongly chitinized and folded back into a projecting ridge; otherwise as in *P. rostrana*.

The larva was not noted.

FAMILY OLETHREUTIDAE

CROCIDOSEMA PLEBEIANA ZELLER

(PL. 99, A; 102, C, D; 103, E; 105, G; 106, B; 108, A–D)

Crocidosema plebeiana Zeller, 1847, *in* Isis von Oken, 1847, Heft 10, p. 721–722.
Eucosma plebeiana Walsingham, 1914, *in* Biol. Centr.-Amer., Lep. Heter., v. 4, p. 231–232.

Up to the present this almost cosmopolitan insect had not been recorded from the United States. Our collecting, however, showed it well distributed and fairly abundant in Texas. In the United States National Museum there are also several adults from California, so that its known range may be said to correspond roughly with the distribution of the Malvaceae. Adults were reared by us from the following plants: *Malvastrum spicatum* (Brownsville, Tex., May, 1919); hollyhock (*Althaea rosea*) (Brownsville, Tex., May, 1919); *Malvaviscus drummondii* (Smith Point, Tex., November, December, 1918; Anahuac, Tex., September, 1918); okra (*Hibiscus esculentus*) (Double Bayou, Tex., November, December, 1918); and *Kosteleyzkya* spp. (Anahuac, Tex., November, 1918). Larvæ were also collected in seed pods of *H. militaris* (Lake Charlotte, Tex., September, 1918) and in flowers of *H. rosa-sinensis* (Smith Point, Tex., November, 1918). They feed chiefly in the seed pods and on the seeds of

the plants infested, but occasionally also on the pollen of the flowers. The species is of special interest because its work and habits are almost identical with those of the genus Pectinophora and also because the larva is frequently pinkish and often has the outer crochets of the prolegs weakly developed or absent. It is easily mistaken for a half-grown pink bollworm. It is readily distinguished, however, by the structural characters here figured (Pl. 102, 103, 105, 106). The linear arrangement of setæ III, IV, and V on the prothorax, the position of III *anterior* to the spiracle on the eighth abdominal segment, the well-developed anal fork (Pl. 105, G), and the olethreutid grouping of the setæ on the ninth abdominal segment (Pl. 103, E) separate it from all the larvæ treated in his paper.

The characters of the pupal abdomen are shown on Plate 108, A–D. *Eucosma discretivana* Heinrich and *E. helianthana* Riley exhibit similar structures, but as neither of these species attacks Malvaceae there is little or no likelihood of confusing them with Crocidosema, We did not find *C. plebeiana* in cotton, but there appears to be no reason why it should not attack that plant; and its possible presence and confusion with the pink bollworm should be borne in mind in cotton inspection.

The male genitalia of the adult are shown in Plate 99, A.

EUCOSMA DISCRETIVANA, N. SP.

(PL. 99, B)

Eucosma discretivana, n. sp.

Antennæ, palpi, face, and head dull, somewhat ashy fuscous. Thorax pale, dull fuscous; tegulæ fuscous with a very slight bronzy tint. Forewings dirty grayish white marked with grayish fuscous; an outwardly angulate grayish fuscous basal patch slightly wider on costa than dorsum; a somewhat paler, semioval patch on dorsum before tornus and extending half way to costa; several narrow, obscure lines of fuscous scales extending outwardly from costa and faintly streaking the white areas; a similar faint line extending from dorsum through middle of white area bordering basal patch; entire termen narrowly margined by pale grayish fuscous: the whitish areas of the wing most pronounced just beyond basal patch and near tornus; cilia grayish; costal fold deeply appressed and reaching nearly to middle of wing. Hindwings dull, smoky fuscous, cilia grayish white with a dull fuscous band along their base. Abdomen grayish fuscous with silvery white scales along the sides and a few scattered silvery scales beneath. Legs fuscous, shading to dirty gray-white on inner sides. Male genitalia of type figured (Pl. 99, B). Alar expanse 13 to 16 mm.

HABITAT.—Sheldon, Tex. (A. C. Johnson).

FOOD PLANT.—"Wild myrtle." Larva boring in the stem and forming a gall.

TYPE.—Cat. No. 23743, United States National Museum.

Described from male type and three male and five female paratypes reared by A. C. Johnson, April 10 to 23, 1919, from larvæ collected by him March 14, 1919.

It is very close to *Eucosma obfuscana* Riley, which it strikingly resembles. The two species are, however, readily distinguishable on both genitalia and slight but constant color differences. In *E. obfuscana* the face, head, thorax, and base of antennæ are inky blue-black, the dark

margin of termen of forewing pronounced and blue-black, extending from the apex only a little over one-half the length of the termen, the white scaling of the tornal area extending into the cilia of the anal angle which are also white. In *E. discretivana* there is none of the blue-black scaling so noticeable in *E. obfuscana*, and the entire termen is faintly dark margined. The cucullus of the harpes of the male genitalia is also more narrowly elongate in *E. obfuscana* than in *E. discretivana*.

The larva is in general structure very like *Crocidosema plebeiana*, except that setæ I, III, IV, and V on the ninth abdominal segment are about equally spaced and the anal fork is lacking. The body is cream-white without markings; chitinized areas about body tubercles not pigmented; hairs whitish yellow; thoracic and anal shields pale yellow, scarcely pigmented; head light brown; crochets brown, 28 to 30, uniordinal and in a complete circle; length, full-grown, 10 to 10.5 mm.

The pupa is similar to that of *Crocidosema plebeiana* but somewhat larger, 8.5 to 9 mm. long by 2.5 mm. wide.

The two species are easily distinguished by their food plants and larval habits.

EUCOSMA HELIANTHANA (RILEY)

Semasia helianthana Riley, 1881, *in* Trans. St. Louis Acad. Sci., v. 4, p. 319.
Thiodia helianthana Dyar, 1903, *in* List North Amer., Lep., no. 5186.
Eucosma helianthana Barnes and McDunnough, 1917, Check List Lep. Bor. Amer., no. 7081.

We found a larva about the size of the pink bollworm and superficially resembling it feeding in the flower heads and on the seeds of the large garden sunflower. It was somewhat pinkish and had a pale kidney-shaped spot on the thoracic shield similar to that of Pectinophora. It had the characteristic olethreutid arrangement of setæ on the ninth abdominal segment and proved to be the caterpillar of *Eucosma helianthana* Riley, a species limited in food plant as far as I know to Helianthus. As the pink bollworm does not attack sunflower and *E. helianthana* does not attack cotton, there is no reason to confuse the two. The structural differences are also easily seen under a binocular or a strong hand lens.

The pupa is similar to that of *Crocidosema plebeiana* but larger, about the size of that of *Eucosma discretivana*.

Larvæ were collected at Dickinson, Tex., September 28, 1918, and pupæ also were found at Smith Point, August 30, 1918. From the latter a moth was reared September 3 of the same year.

LASPEYRESIA TRISTRIGANA (CLEMENS)

Stigmonota tristrigana Clemens, 1865, *in* Proc. Ent. Soc. Phila., v. 5, p. 133.
Enarmonia tristrigana Dyar, 1903, List North Amer. Lep., no. 5275.
Laspeyresia tristrigana Barnes and McDunnough, 1917, Check List Lep. Bor. Amer., no. 7220.

On the prairie lands and along the fences adjoining fields that had been planted in cotton the previous year (1917) we frequently found a white

and pinkish larva feeding on the seeds of *Baptisia* spp. about the size and with much the general appearance of the pink bollworm. Except for the complete circle of crochets on the prolegs the superficial resemblance was rather striking. The structural characters are so obviously different as to prevent confusion by a careful observer. The arrangement of setæ on the ninth abdominal segment is typically olethreutid (Compare Pl. 103, E; 105, B), and the grouping of the head setæ is also quite different from that of the pink bollworm; A^1, A^2, A^3, and L^1 lie in almost a straight line, and the puncture A^a is well back of (almost directly posterior to) A^3 rather than between it and A^1 as in *Pectinophora gossypiella*.

The larva is most like that of *Eucosma helianthana*, from which it differs in the size of the head, the color of the thoracic shield, and the position of epicranial puncture A^a. In *E. helianthana* the puncture (A^a) lies to the side directly dorsad of seta A^2, between it and the adfrontal suture, the head is smaller in the full-grown larva, and the thoracic shield is brown with a more or less distinct hyaline kidney-shaped spot on the side. In *Laspeyresia tristrigana* the shield is of the general body color with a few small, irregular, scattered yellow spots. Neither species has an anal fork.

The pupa is similar to that of *Crocidosema plebeiana*.

Several adults were reared during May, 1919, from larvæ collected in August, 1918 (Anahuac, Tex.) and in November, 1918 (El Vista, Tex.).

FAMILY PHALONIIDAE

PHALONIA CEPHALANTHANA, N. SP.

(PL. 100, A)

Phalonia cephalanthana, n. sp.

Antennæ grayish black, palpi dull yellow, whitish above and on inner sides. Face whitish. Head yellow. Thorax mahogany-red. Forewings brownish overlaid with mahogany-red mixed with a few blackish scales, the red scaling unevenly distributed, forming an obscure but distinguishable outwardly angulate basal patch, a broad, vertical, somewhat irregular median fascia, and a moderately broad, outwardly oblique costal dash near apex, the latter extending from apical fifth of costa to below middle of termen; other areas of wing brown, more or less streaked with reddish or black scales; cilia mixed brown, red, and black. Hind-wings smoky gray; underside faintly mottled; cilia grayish white. Legs heavily dusted on outer sides with grayish black; ends of joints and inner sides yellowish white. In general appearance to the naked eye the insect is a rather pale wine-red, blotched with darker shading of the same color. Male genitalia of type figured (Pl. 100, A). Alar expanse 8 to 10 mm.

HABITAT.—Shores of Lake Charlotte, Chambers County, Tex. (Heinrich).

FOOD PLANT.—*Cephalanthus occidentalis*.

TYPE.—Cat. No. 23744, United States National Museum.

Described from male type and 16 male and female paratypes reared September 16 to 24, 1919, from larvæ collected September 10, 1918; a distinct and easily recognized species.

The larva feeds in the seed pods. It is a dirty white with the chitinized areas about the body tubercles conspicuous, moderately large, round or oval, and a dull smoky fuscous, the chitinizations becoming heavier and more extended toward the caudal end; on the eighth abdominal segment paired setæ I are on a single chitinization; also paired II; on the ninth abdominal segment paired II, I, and III are on a single shield; the setal arrangement of the ninth abdominal segment is similar to that of the Olethreutidae with I and III rather closely approximate; seta III on eighth abdominal segment directly anterior to the spiracle; anal shield brown; anal fork developed, 6-pronged; crochets of prolegs uniordinal and arranged in a complete circle, 36 to 40; skin finely granulate; thoracic legs pale; thoracic shield the color of body except for a shading of yellow along hind margins. Head yellow, shading to yellowish brown; ocellar pigment slight, continuous but not filling the ocellar area; setæ of anterior and lateral group (A^1, A^2, A^3, and L^1) crowded well forward on head; A^1, A^2, and A^3 forming a slightly acute angle; L^1 closely approximate to A^3. Full-grown larva 8 to 9 mm. long.

The pupa is similar to that of *Crocidosema plebeiana* except that the caudal end is more rounded. There is no cremaster.

FAMILY AEGERIIDAE

ZENODOXUS PALMII (NEUMOEGEN)

Larunda palmii Neumoegen, 1891, *in* Ent. News, v. 2, p. 108.
Paranthrene palmii Beutenmüller, 1901, *in* Mem. Amer. Mus. Nat. Hist., v. 1, pt. 6, p. 316.
Paranthrene palmii Dyar, 1903, List North Amer. Lep., no. 4260.
Zenodoxus palmii Barnes and McDunnough, 1917, Check List Lep. Bor. Amer., no. 6735.

Several specimens of this species were reared during April and May, 1919, from larvæ collected at Brownsville, Tex., January 23 and February 3, 1919, by H. C. Hanson and E. L. Diven. The caterpillars bore in the stems of *Wissadula lozani* and are usually found well down in the stems at the base of the plants near the roots. The adults agreed very well with the description of *Zenodoxus palmii* Neum. I have since compared them with the type in the Brooklyn Institute and have little hesitation in determining them as that species, although they are a trifle small (alar expanse 17.5 to 21 mm.).

The larvæ of this family are not likely to be confused with those of the pink bollworm and are easily identified by the peculiar arrangement of the ocelli—that is, with ocelli I to IV grouped together forming a trapezoid and V and VI well separated from the other four—and the crochets of the prolegs. The latter are always uniordinal and *in two transverse* bands. The setæ on the ninth abdominal segment are much the same as in the Olethreutidae.

The pupæ have two rows of strong spines on the dorsum of several of the abdominal segments as in the Tortricidae, but the wings are narrow and pointed, the maxillary palpi are large and conspicuous, and the thoracic spiracle is normally well developed; thus they are distinguished readily enough from pupæ of the latter group.

FAMILY PTEROPHORIDAE

EDEMATOPHORUS VENAPUNCTUS, N. SP., BARNES AND LINDSEY [1]

During April and May, 1919, Mr. E. L. Diven reared eight specimens of a pterophorid moth from larvæ feeding on the leaves of a composite at Brownsville, Tex. These were referred to Mr. Lindsey, who determined them as *Oedematophorus venapunctus*, an unpublished species, which he and Dr. Barnes had recently described from collected material.

The species is not a malvaceous feeder and has no special interest here apart from the rearing record and the structural peculiarities of the larva and pupa which, while strikingly modified in this particular form, will serve, nevertheless, to exemplify the family.

The pterophorid larvæ have only two setæ on the prespiracular shield of the prothorax and setæ IV and V approximate on the proleg-bearing abdominal segments, as in the Pyralidae with which they are affiliated. They have, however, in distinction from the Pyralidae proper, long stemlike prolegs and a greater or less development of secondary setæ. The crochets are also peculiar, being uniordinal, few in number (6 to 8 in the genus Oedemataphorus), and arranged in a quarter circle opening outwardly. In *O. venapunctus* the secondary hairs are confined to a row

[1] Inasmuch as the foregoing name was desired for this paper in advance of their proposed revision of the Pterophoridae Drs. Wm. Barnes and A. W. Lindsey have kindly furnished the following description:

Oedematophorus venapunctus, n. sp., Barnes and Lindsey.

Head whitish ochreous between the antennæ, elsewhere light brown. Antennæ and palpi pale brownish ochreous, almost white, the latter short, oblique or porrect. Thorax and legs of the same shade of pale brownish ochreous, the fore and middle legs tinged with brown inside. Abdomen similar both above and below, with a fine, brown, middorsal line.

Primaries concolorous with thorax, darker toward costa, especially in first lobe, though this shade is scarcely evident in some specimens. Just before and below the base of the cleft is a small blackish brown spot, isolated except in our darkest specimen, in which it is continued obliquely toward the costa by a faint dark shade. In the outer margin of the second lobe there are four short, dark dashes on the tips of the anal, cubital, and third median veins. These are very faint in some specimens. A similar but heavier spot occurs on the inner margin of the first lobe a short distance before its apex at the tip of the fifth radial. Two vague dots sometimes appear on the costal margin of this lobe, one just before the apex and the other almost opposite the one on the inner margin. Fringes concolorous, slightly darker toward the apex of the wing and with their bases slightly paler. Secondaries somewhat paler than primaries and with a more grayish tinge. Fringes concolorous with slightly paler bases.

Expanse 15 to 18 mm.

Described from the following series: Holotype male, Brownsville, Tex., March; paratype male, same locality; allotype and six paratypes females, San Benito, Tex., March and April. (Collection Barnes).

Paratype male, Brownsville, Tex., March, and paratype female, from San Benito, Tex., April, in United States National Museum, type Cat. no. 23495.

This species appears to be allied to *Oedematophorus palcaceus*, *O. stramineus*, *O. kellicotti*, and related species. It differs from the first two in the presence of the terminal dots and from the last two in that the dot in the disc of the primaries is not contiguous to the base of the cleft. The form of the male genitalia also differs from that of any related species known to us. We have been unable to place it as a described Mexican or Central American species.

of 5 to 8 in the area normally occupied by seta VI. The body tubercles are somewhat produced, especially on the prothorax and tenth abdominal segment, and the hairs themselves are swollen and bulbous. In addition to the setæ there are on all except the first thoracic and the last abdominal segments several fingerlike projections from the skin. On the abdomen these arise back of setæ I, II, III, IV, and V from the base of their tubercles and in the area back of the spiracle and seta group IV–V. The prothorax is somewhat produced dorsally, and the head is capable of retraction under the cover of this rooflike projection.

In the pupa the venter of the eighth, ninth, and tenth segments is deeply concave with the lateral edges fringed by rather short flexible setæ. The ventral edge of the tenth segment and the anterior margins of the concavity are also armed with clusters of slender, hooked hairs. The caudal end is sharply pointed, but there is no distinct cremaster.

The larva is an external feeder, and the pupal period is very short. Larvæ collected by Diven from April 7 to 14, 1919, produced moths as early as the ninteenth of the same month.

FAMILY PYRALIDAE

SUBFAMILY THYRIDINAE

MESKEA DYSPTERARIA GROTE

(PL. 101, E, F; 104, B; 109, A–E)

Meskea dyspteraria Grote, 1877, *in* Canad. Ent., v. 9, p. 115.
Meskea dyspteraria Dyar, 1903, List North Amer. Lep., no. 4139.

This species was described by Grote from a single female collected in Bastrop County, Tex. Up to the present it has been rare in collections, Grote's type and a male from the Riley collection being the only representatives in the United States National Museum. Nothing was known of its larval habits or life history. We succeeded in rearing a large series of the moths and found their larvæ rather abundant though locally distributed. The larvæ mine the stems of several malvaceous plants, forming a conspicuous, elongate gall. The species seems to favor Malvaviscus and Abutilon; but occasional larvæ were found in galls on *Kostelelzkya* sp. (Anahuac, Tex., Aug. 13–14, 1918, More and Diven, collectors). The species overwinters as larvæ in the gallery, pupating in the spring and producing moths during April and May. From larvæ collected in *Malvaviscus drummondii* at Wallisville, Tex., September 3, 1918 (Hanson, Diven, and Heinrich), October 28, 1918 (Hunter, Busck, and Johnson), and November 5, 1918 (Barber, More, and Heinrich) moths were reared during May 9 to 25, 1919; in *M. drummondii* taken along the San Jacinto River near Crosby, Tex. (Hanson), November 6, 1918, moths issued May 4 to 10, 1918. Larvæ taken in *Abutilon berlandieri*, at Brownsville, Tex., December 31, 1918, and in *A. incanum* at Barreta, Tex., January 5,

1919 (Hanson) pupated the latter part of March and produced moths from April 5 to May 22, 1919. Neither larva nor work were found in cotton or okra or on any of the various species of Hibiscus, though there appears to be no reason why these plants should escape.

The full-grown larva is somewhat larger than a mature pink bollworm (22–22.5 mm. long) and is easily distinguished from it by the pyralid arrangement of the body setæ (*two* setæ only on prespiracular shield of prothorax and IV and V approximate on proleg-bearing abdominal segments). The structural characters of larva and pupa are fully illustrated in Plates 101, 104, and 109. These and the larval habits will serve to identify the species and distinguish it readily from any other lepidopteron of similar food plant and habits.[1]

SUBFAMILY PYRAUSTINAE

NOCTUELIA RUFOFASCIALIS (STEPHENS)

Ennychia rufofascialis Stephens, 1834, Illus. Brit. Ent., Haust, v. 4, p. 33.
Botys (?) thalialis Walker, 1859, List Lep. Brit. Mus., pt. 18, p. 582.
Noctuelia thalialis Hampson, 1899, *in* Proc. Zool. Soc. London, pt. 1, p. 279, 1899.
Noctuelia thalialis Dyar, 1903, List North Amer. Lep., no. 4478.
Noctuelia rufofascialis Barnes and McDunnough, 1918, Contrib. Nat. Hist. Lep. North Amer., v. 4, no. 2, p. 167.

The larva of this species is a seed-feeder in pods of Abutilon, Wissadula, Malvastrum, Sida, and possibly other malvaceous or similar plants. It feeds in much the same way as the pink bollworm and pupates in a thin cocoon either in the empty seed pod or on the outside of the plant. Two larvæ were taken at Brownsville, Tex., April 11, 1919, by Diven feeding in the young terminal shoots of cotton. This habit, however, is unusual. When full-grown the larva is about the size of a full-fed pink bollworm and seems ridiculously large for the small seed pods within which it must accommodate itself. It is very strikingly and beautifully marked and very similar to the caterpillers of *Gelechia bosquella* Chambers and *Borkhausenia diveni*, elsewhere mentioned in this paper. It is readily distinguished from them by the pyraloid setal arrangement of the prothorax (two setæ only in the prespiracular group). The general body color is white with the thoracic segments and anterior half of the first abdominal segment a deep wine-red. The remaining abdominal segments are also partially encircled by a broad band of the same color. The head is light yellow, and the thoracic and anal shields are yellow or brownish, the legs smoky fuscous, and the crochets of the prolegs (7 to 10) *uniordinal and arranged in a circle broken outwardly* as in the pink bollworm—a very unusual structure in this subfamily.

[1] It should be noted that puncture A^a on the epicranium is somewhat differently located on different specimens, sometimes higher, sometimes lower, occasionally even lying between seta A^3 and L^1 and frequently differently placed on opposite sides of the same head. Body seta IV on abdominal segment 9 is also very often absent. When present it is always short and inconspicuous.

Adults were reared during May, 1919, from larvæ collected in pods of Abutilon and Malvastrum at Brownsville, Tex., December 27, 1918 (Hanson), and April 12, 1919 (Diven). Other larvæ were collected in seed pods of Wissadula and Sida at Brownsville, but no adults were reared. The species is not common and we found it only in the vicinity of Brownsville.

PACHYZANCLA BIPUNCTALIS (FABRICIUS)

Phalaena bipunctalis Fabricius, 1794, Ent. Syst., t. 3, pars 2, p. 232.
Pachyzancla bipunctalis Dyar, 1903, List North Amer. Lep., no. 4344.

Several moths of this species were reared September 14 to 18, 1918, from larvæ tying the terminal leaves and feeding on the seeds of the common pigweed (*Amaranthus hybridus*). Larvæ were collected at Turtle Bayou, Tex., September 4, 1918.

The caterpillars are typical Pyraustinae with the proleg crochets *triordinal* and arranged in a penellipse.

All the Pyralidae are distinguished by having *two setæ* on the prespiracular shield of the prothorax (IV and V) and IV and V approximate on the proleg-bearing abdominal segments (compare Pl. 103, B; 104, B). No other group posesses this combination.

GLYPHODES PYLOALIS WALKER

Glyphodes pyloalis Walker, 1859, List Lep. Brit. Mus., pt. 19, p. 973-974.
Glyphodes pyloalis Hampson, 1899, *in* Proc. Zool. Soc. London, 1898, pt. 4, p. 746.

On a private estate near Alto Loma, Tex., the writer found a number of pyralid larvæ tying and feeding on the leaves of a mulberry tree. A moth was reared from these which both Mr. Schaus and Dr. Dyar have determined as *Glyphodes pyloalis* Walker. This record is of interest because *G. pyloalis* Walker is a Chinese species which has not hitherto been recorded from the United States. Unfortunately as the single reared specimen is a female the genitalia could not be compared with those of oriental specimens.

The larvæ were collected September 27, 1918. All died during the winter except one which pupated about the middle of April, 1919. The moth issued April 19, 1919.

SUBFAMILY CRAMBINAE

DICYMOLOMIA JULIANALIS (WALKER)

(PL. 101, C, D; 103, B; 106, D; 108, E-H)

Cataclysta (?)julianalis Walker, 1859, List Lep. Brit. Mus., pt. 17, p. 438.
Dicymolomia julianalis Dyar, 1903, List N. Am. Lep., no. 4634.

The larva of this species is the caterpillar popularly known in the cotton areas of Texas as the "white worm" and is the one most easily and frequently confused with the pink bollworm. The two when full-grown are about the same size, and both have the crochets on the

prolegs arranged in a circle broken outwardly. *Dicymolomia julianalis* is also frequently found in cotton bolls. Its normal and favored food plant is cattail (*Typha* sp.) in the spike of which it feeds and undergoes its transformation. In some parts of Texas, however, we also found it commonly in old and diseased cotton bolls, feeding upon the lint and in some cases the cotton seeds. We did not, however, find it in any green or healthy bolls. Larvæ were collected in the region about Beaumont during November, 1918, and near Brownsville from December, 1918, until early April, 1919. Adults issued from the latter part of March until the middle of May. The species overwinters in the larval stage, the caterpillars remaining in the fallen and rotting bolls and pupating during February and early March.

While very similar in superficial appearance to the pink bollworm and easily mistaken for it by one not familiar with larval characters, the caterpillar of *Dicymolomia julianalis* is easily distinguished on structure. The position of the anterior puncture (A^a) of epicranium back of seta A^2 and the presence of *only two* setæ on the small shield anterior to the prothoracic spiracle at once separates it from Pectinophora.

The pupa is smooth except for the normal body seta and a half dozen slender hooked spines on the cremaster and is not likely to be mistaken for that of *Pectinophora gossypiella*.

The structural characters of both larva and pupa are fully figured in Plates 101, 103, 106, and 108.

SUBFAMILY PHYCITINAE

MOODNA OSTRINELLA (CLEMENS)

(PL. 104, E)

Ephestia ostrinella Clemens, 1861, *in* Proc. Acad. Sci. Phila., 1860, p. 206.
Manhatta ostrinella Hulst, 1903, *in* Dyar, List North Amer. Lep., no. 4886.
Moodna ostrinella Barnes and McDunnough, 1917, Check List Lep. Bor. Amer., no. 5795.

The larva of this species is a scavenger feeding in diseased cotton bolls in company with and in much the same manner as *Dicymolomia julianalis*. It is a smaller caterpillar (8 to 9.5 mm. long) when full-grown. The heavy, ringlike chitinization about tubercles II^b of the mesothorax and III of the eighth abdominal segment (Pl. 104, E), which is so conspicuous a feature on this and the following larva (*Homocosoma electellum*), is a character found upon most phycitine larvæ but nowhere else, so far as I know, outside of this subfamily.

The caterpillar of *Moodna ostrinella* is a nearly uniform dirty white; thoracic shield smoky fuscous divided on dorsum by a wide median whitish line; body tubercles dark brown; skin finely granulate; body hairs moderately long, pale yellowish; legs whitish, ringed with smoky fuscous; head pale yellowish brown; labrum and anterior margins of epicranium blackish brown; ocellar pigment a black spot under each

ocellus, not continuous; crochets evenly biordinal, alternating one long and one very short hook, 40 to 44.

Larvæ collected November 24, 1918, at Kountz, Tex. Moth issued April 7, 1919.

HOMOEOSOMA ELECTELLUM (HULST)

(PL. 100, B)

Anerastia electella Hulst, 1887, *in* Entomologica Americana, v. 3, p. 137–138.
Homoeosoma electellum Hulst, 1903, *in* Dyar, List North Amer. Lep., no. 4865.

A large series of moths was reared April 23 to May 5, 1919, from larvæ collected at Brownsville, Tex., April 7, 1919, by E. L. Diven. The larvæ feed in the flower heads of a composite, making an untidy patch and eating the bloom, stem, and seeds. The species appeared to be very common.

The larva is pale smoky brown, longitudinally marked by two narrow white dorsal stripes and a similar lateral stripe; spiracles black, thoracic legs smoky fuscous; anal shield yellow, thoracic shield yellow, broadly margined laterally and posteriorly with black; head pale yellow, mottled with yellowish brown and with a broad lateral black band and a blackish shading toward anterior margins of epicranium; ocelli distinct; ocellar pigment absent or confused in the lateral black of epicranium; general structural characters as in *Moodna ostrinella;* width 6 to 7 mm.

The interesting and rather complicated genitalia of the male adult are figured in Plate 100, B.

SUBFAMILY CHRYSAUGINAE

CLYDONOPTERON TECOMAE RILEY

Clydonopteron tecomae Riley, 1880, *in* Amer. Ent., v. 3, no. 12, p. 288.
Salobrana tecomae Dyar, 1903, List North Amer. Lep., no. 4526.
Clydonopteron tecomae Barnes and McDunnough, 1917, Check List Lep. Bor. Amer., no. 5283.

The larva of this species feeds only in the seed pods of the trumpet-flower vine (*Tecoma radicans*). It is mentioned here only because its host plant is often found in the neighborhood of the cotton fields and for that reason it might be confused by the uncritical with the larva of *Pectinophora gossypiella*. It is easily distinguished, however. The spiracles are rather large, oval, and black, the edges are heavily chitinized, and the spiracle on the eighth abdominal segment is somewhat larger but no higher on the body than the others; the proleg crochets are arranged as in the Aegeriidae—that is, uniordinal and in two transverse bands—and the prothorax has only *two* setæ on the chitinization before the spiracle as in other Pyralidae. It pupates in a cocoon within the seed pod.

Moths were reared by us August 30 to September 15, 1918, from larvæ collected earlier in August (Anahuac, Tex.) the same year.

FAMILY NOCTUIDAE

Several species of this family feed upon cotton and malvaceous plants. They are easily distinguished from the pink bollworm or larvæ of any of the other groups treated in this paper by the arrangement of the body setæ and the crochets of the prolegs. Like the Pyralidae they have only two setae (IV and V) on the prespiracular shield of the prothorax, but the position of IV and V on the proleg-bearing segments is quite different, IV being *remote* from V and directly back of the spiracle (Pl. 103, D). The crochets of the prolegs are also arranged in a mesoseries (Pl. 106, E).

The following species were reared.

SUBFAMILY AGROTINAE

HELIOTHIS (CHLORIDEA) OBSOLETA (FABRICIUS)

(PL. 103, D; 106, E)

Bombyx obsoleta Fabricius, 1793, Ent. Syst., t. 3, pars. 1, p. 456.
Heliothis armiger Dyar, 1903, List North Amer. Lep., no. 2300.
Chloridea obsoleta Hampson, 1903, *in* Cat. Lep. Phal. Brit. Mus., v. 4, p. 45, 657.
Heliothis obsoleta Barnes and McDunnough, 1917, Check List Lep. Bor. Amer., no. 1090.

This species is commonly known as the "corn earworm" or "cotton bollworm." It feeds on a number of plants and often attacks cotton, doing serious damage in some localities. The larva bores into the bolls, making a large hole and destroying lint and seeds.

One moth was reared from a larva feeding on the leaves of *Malvaviscus drummondii* at Brownsville, Tex. A larva was collected by E. L. Diven, May 7, 1919. The adult emerged May 29 of the same year.

HELIOTHIS (CHLORIDEA) VIRESCENS (FABRICIUS)

Noctua virescens Fabricius, 1781, Spec. Insect., t. 2, p. 216.
Chloridea virescens Dyar, 1903, List North Amer. Lep., no. 2296.
Chloridea virescens Hampson, 1903, *in* Cat. Lep. Phal. Brit. Mus., v. 4, p. 48.
Heliothis virescens Barnes and McDunnough, 1917, Check List Lep. Bor. Amer., no. 1091.

This species has very much the same habits as *Heliothis obsoleta* Fabricius. Moths were reared September 8 and 17, 1919, from larvæ taken feeding on seeds in okra pods August 19, 1918, at Double Bayou, Tex. (E. L. Diven).

SUBFAMILY ACRONYCTINAE

BAGISARA RECTIFASCIA (GROTE)

Schinia rectifascia Grote, 1874, *in* Proc. Boston Soc. Nat. Hist., v. 16, 1873/74, p. 242.
Atethmia rectifascia Dyar, 1903, List North Amer. Lep., no. 2267.
Bagisara rectifascia Hampson, 1910, *in* Cat. Lep. Phal. Brit. Mus., v. 9, p. 156.

One moth was reared September 1 and one September 23, 1918, from larvæ collected on *Malvaviscus drummondii* August 10, 1918 (Anahuac, Tex., J. D. More). Dr. Dyar, who determined the Noctuidae, informs me that the larva of this species has not been described. Unfortunately those preserved with the foregoing experiment are Catocalinae of some kind and probably have no connection with the adults reared.

SUBFAMILY EREBINAE

ALABAMA ARGILLACEA (HÜBNER)

Aletia argillacea Hübner, 1820, Zutr. Samml. Exot. Schmett., fig. 399.
Alabama argillacea Dyar, 1903, List North Amer. Lep., no. 2555.

Several moths were reared from larvæ feeding on the cotton leaves. Larvæ were taken September 25, 1918, at Dickinson, Tex., and moths early in October of the same year. The species pupates within the folded leaves on the plant.

ANOMIS EXACTA HÜBNER

Anomis exacta Hübner, 1810, Samml. Exot. Schmett., v. 2, pl. 411.
Anomis exacta Dyar, 1903, List North Amer. Lep., no. 2557.

One moth was reared September 1, 1918, from a larva collected on *Malvaviscus drummondii*, Anahuac, Tex., August 14, 1918 (J. D. More). The larva pupated August 21, spinning a loose tie of several leaves.

ANOMIS EROSA HÜBNER

Anomis erosa Hübner, 1818, Zutr. Samml. Exot. Schmett., fig. 287.
Anomis erosa Dyar, 1903, List North Amer. Lep., no. 2556.

One moth from Brownsville, Tex., January 19, 1919, was reared from a pupa in the tied leaves of *Abutilon incanum* (H. C. Hanson, collector).

FAMILY LYCAENIDAE

STRYMON MELINUS HÜBNER

Strymon melinus Hübner, 1818, Zutr. Exot. Schmett., fig. 121.
Uranotes melinus Dyar, 1903, List North Amer. Lep., no. 335.
Strymon melinus Barnes and McDunnough, 1917, Check List Lep. Bor. Amer., no. 352.

This caterpillar feeds on a great variety of plants, including practically all the Malvaceae. On cotton it attacks the flowers and bolls, boring into the latter and feeding upon lint and seeds and making, when half-

grown, a hole which reminds one very much of the exit hole made by a pink bollworm.

The larva itself looks nothing like any of the others here treated. It is spindle-shaped, sharply tapering at each end, broad in the middle in proportion to its length, with a small head, the body covered with fine stiff secondary hairs, and greenish yellow in color.

In addition to cotton we find it frequently on okra, *Kosteletzkya* spp., *Malvaviscus drummondii*, and *Hibiscus* spp. On these it fed on the seeds, boring into the seed pods, or upon the blossoms.

The table of larval characters will serve to place the forms here treated. The characters given are not to be understood as diagnostic in all cases. In the Cosmopterygidae, for example, seta I is often as far from III as it is from II as in the Gelechiidae or the Oecophoridae. There are also a few exceptions to the gelechiid character (the remoteness of epicranial seta L^1 from A^3). The characters hold, however, for all the species here treated occurring on Malvaceae.

Characters of larvæ likely to be confused with the pink bollworm

1. Body depressed and spindle-shaped, covered with secondary setæ. . LYCAENIDAE.
   Body otherwise 2
2. Setae IV and V on proleg-bearing abdominal segments closely approximate . . 3
   Setae IV and V on proleg-bearing abdominal segments well-separated 13
3. Prespiracular shield of prothorax bearing two setæ only 4
   Prespiracular shield of prothorax bearing three setæ 5
4. Prolegs long and slender; body of larvæ normally with one or more secondary setæ . . . . PTEROPHORIDAE.
   Prolegs otherwise; body with only primary setæ . . . . PYRALIDAE.
5. Body with one or more secondary setæ . . . . ETHMIIDAE.
   Body with only primary setæ 6
6. Ocelli I to IV grouped together, forming a trapezoid; ocelli V and VI fairly close together but well-separated from the other four . . . . AEGERIIDAE.
   Ocelli otherwise 7
7. Paired dorsal setæ II on ninth abdominal segment closer together than paired I on dorsum of eighth abdominal segment; usually on a single chitinization 8
   Paired dorsal setæ II on ninth abdominal segment at least as far apart as paired I on eighth abdominal segment and not on a single chitinization . . 9
8. Setæ I and III closely approximate on ninth abdominal segment 10
   Setæ I and III not closely approximate on ninth abdominal segment TORTRICIDAE.
9. Epicranial seta L^1 remote from A^3 (farther from A^3 than A^3 is from A^2) GELECHIIDAE.
   Epicranial seta L^1 approximate to A^3, at least no farther from A^3 than A^3 is from A^2 11
10. Seta II^a on prothorax higher than I^a . . . . COSMOPTERYGIDAE. (in part: *Pyroderces rileyi*).
    Seta II^a on prothorax not higher than I^a . . . . OLETHREUTIDAE. PHALONIIDAE.
11. Prothoracic legs very close together, coxæ touching . . . . BLASTOBASIDAE.
    Prothoracic legs appreciably separated 12

12. Setæ III on abdominal segments I to VII antero-dorsad of and close to the spiracle..STENOMIDAE.
Setæ III on abdominal segments I to VII dorsad of the spiracle; if occasionally somewhat antero-dorsad not close to the spiracle.....OECOPHORIDAE.
13. Seta IV directly behind the spiracle on proleg-bearing abdominal segments; crochets of prolegs arranged in a mesoseries; two setæ only on prespiracular shield of prothorax; no secondary hair on body or head..........NOCTUIDAE. (in part, as here represented).

PLATE 93

Male genitalia (Gelechiidae):

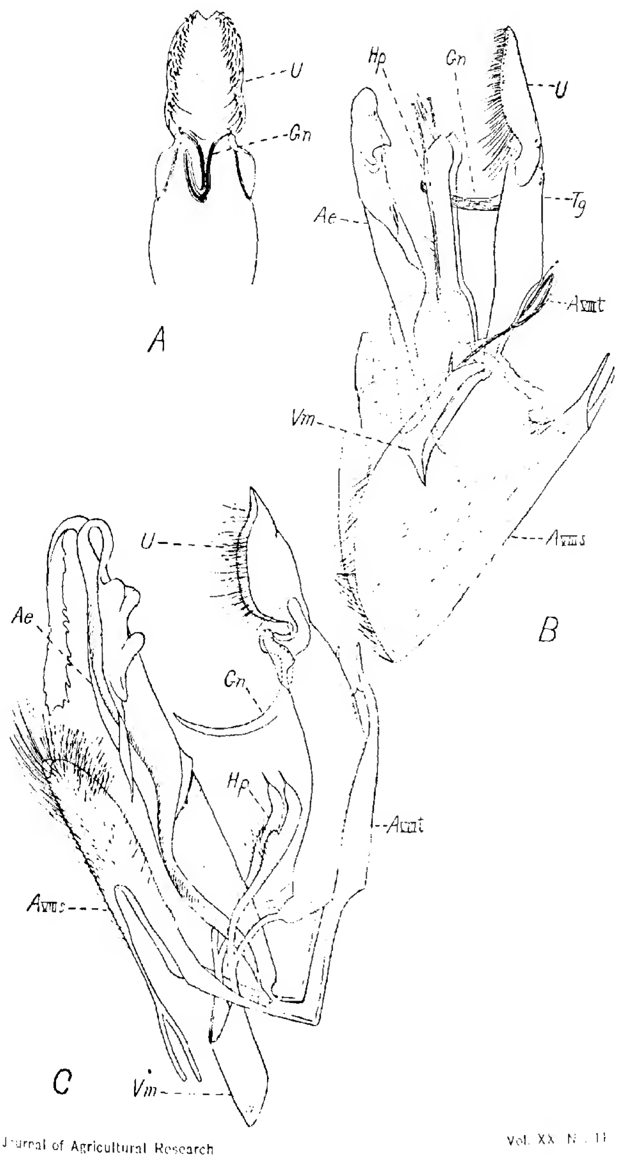
A.—*Gelechia trophella:* Posterior part of tegumen, showing uncus and gnathos, ventral view.

B.—*G. trophella:* Lateral view of male genitalia with eighth abdominal segment attached.

C.—*G. hibiscella:* Lateral view of male genitalia with eighth abdominal segment attached.

Explanation of symbols applied to male genital organs on Plates 93–100.

Ae=aedoeagus (outer chitinous sheath of penis).
An=anellus (chitinous support of aedoeagus).
Ao=opening in tegumen through which anal tube passes.
Cl=clasper on harpe.
Cn=cornutus (cornuti) spine or spines on penis proper.
Cs=cucullus of harpe.
Gn=gnathos.
Hp=harpe.
Si=soci.
Tg=tegumen.
Ts=transtilla (a costal bridge, or sometimes elements thereof not united; connecting the harpes).
Vm=vinculum.
U=uncus.
A VIIIs=sternite of eighth abdominal segment.
A VIIIt=tergite of eighth abdominal segment.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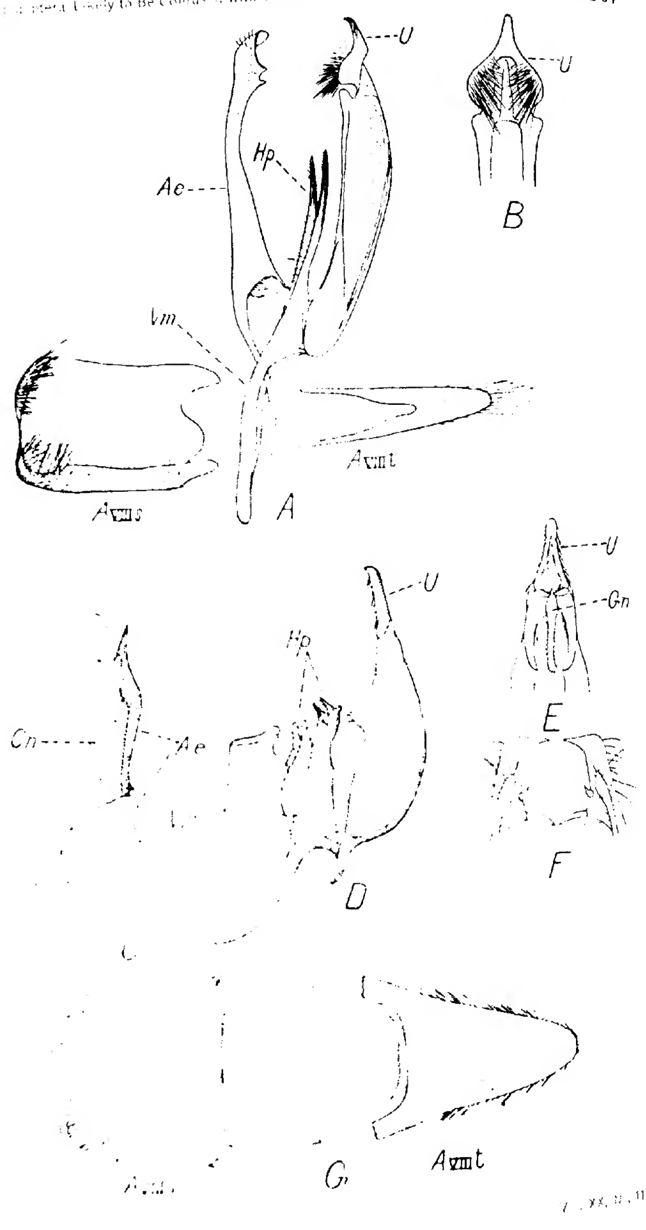
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PLATE 94

Male genitalia (Gelechiidae):

A.—*Telphusa mariona* (type): Lateral view of male genitalia.

B.—*T. mariona* (type): Posterior part of tegumen, showing uncus, ventral view.

C.—*Gelechia neotrophella* (type): Aedoeagus and penis.

D.—*G. neotrophella* (type): Lateral view of male genitalia with ædoeagus and eighth segment removed.

E.—*G. neotrophella* (type): Posterior part of tegumen, showing uncus and gnathos, ventral view.

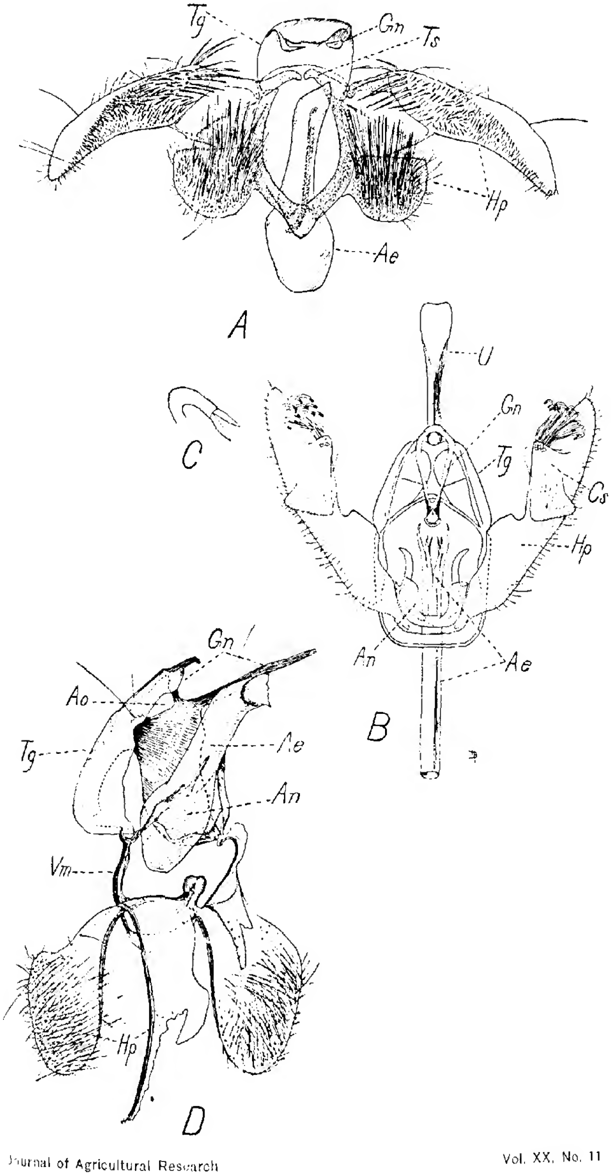
F.—*G. neotrophella* (type): Posterior half of harpes, ventral view.

G.—*G. neotrophella* (type): Sternite and tergite of modified eighth abdominal segment.

PLATE 95

Male genitalia (Gelechiidae, Stenomidae, and Oecophoridae):

A.—*Isophrictis similiella:* Ventral view of male genitalia, spread.
B.—*Aedemoses haesitans:* Ventral view of male genitalia, spread.
C.—*A. haesitans:* Enlargement of typical split hair on cucullus.
D.—*Borkhausenia fasciata:* Ventro-lateral view of male genitalia, spread, showing asymmetrical armlike projections from gnathos and costa of harpes.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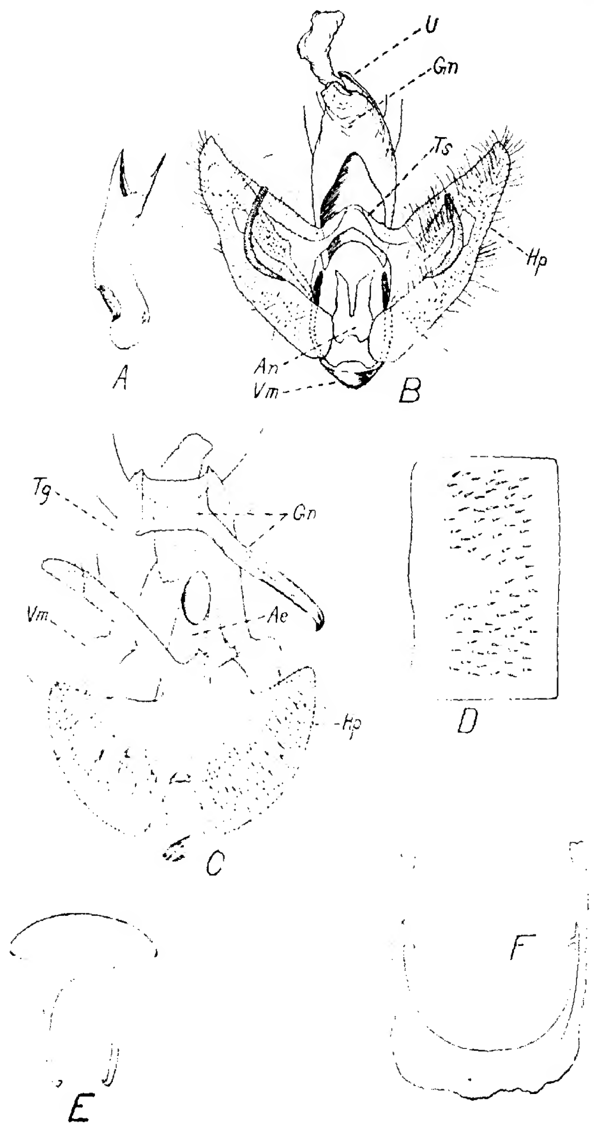
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PLATE 96

Male genitalia (Oecophoridae):

A.—*Borkhausenia minutella:* Aedoeagus.

B.—*B. minutella:* Ventral view of male genitalia, spread, aedoeagus omitted.

C.—*B. diveni* (type): Ventral view of male genitalia, spread.

D.—*B. diveni* (type): Dorsal view of an abdominal segment showing spinose condition of abdomen.

E.—*B. diveni* (type): Modified tergite of eighth abdominal segment.

F.—*B. diveni* (type): Modified sternite of eighth abdominal segment.

PLATE 97

Male genitalia (Oecophoridae):

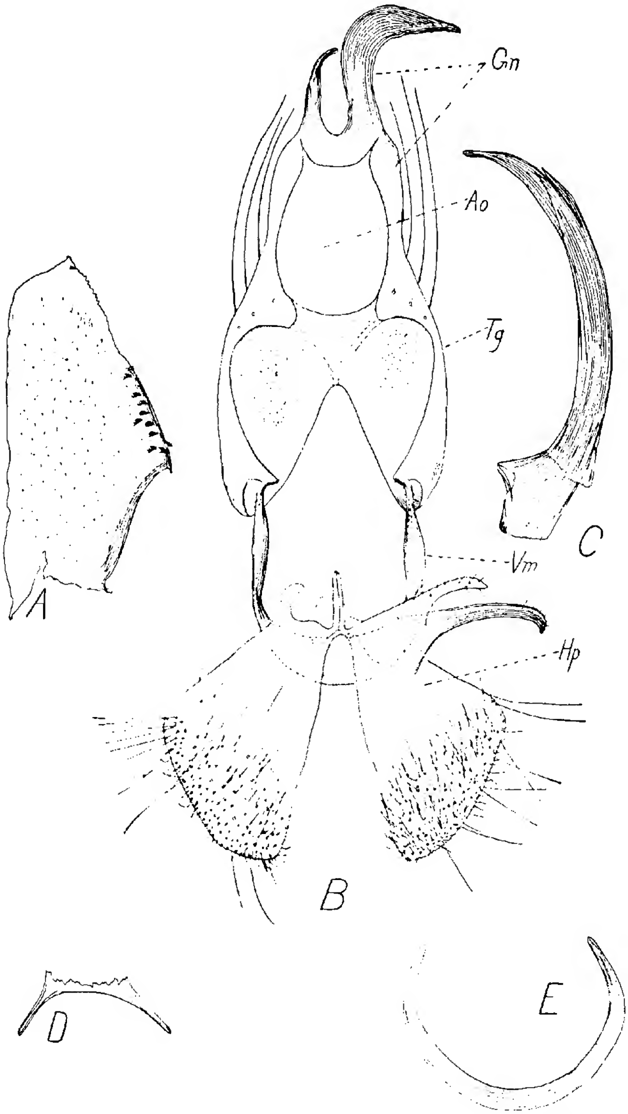
A.—*Borkhausenia conia:* Portion of tergite of seventh abdominal segment, showing spinose and chitinized character of caudal margin.

B.—*B. conia:* Ventral view of male genitalia, spread, aedoeagus omitted.

C.—*B. conia:* Aedoeagus.

D.—*B. conia:* Modified tergite of eighth abdominal segment.

E.—*B. conia:* Modified sternite of eighth abdominal segment.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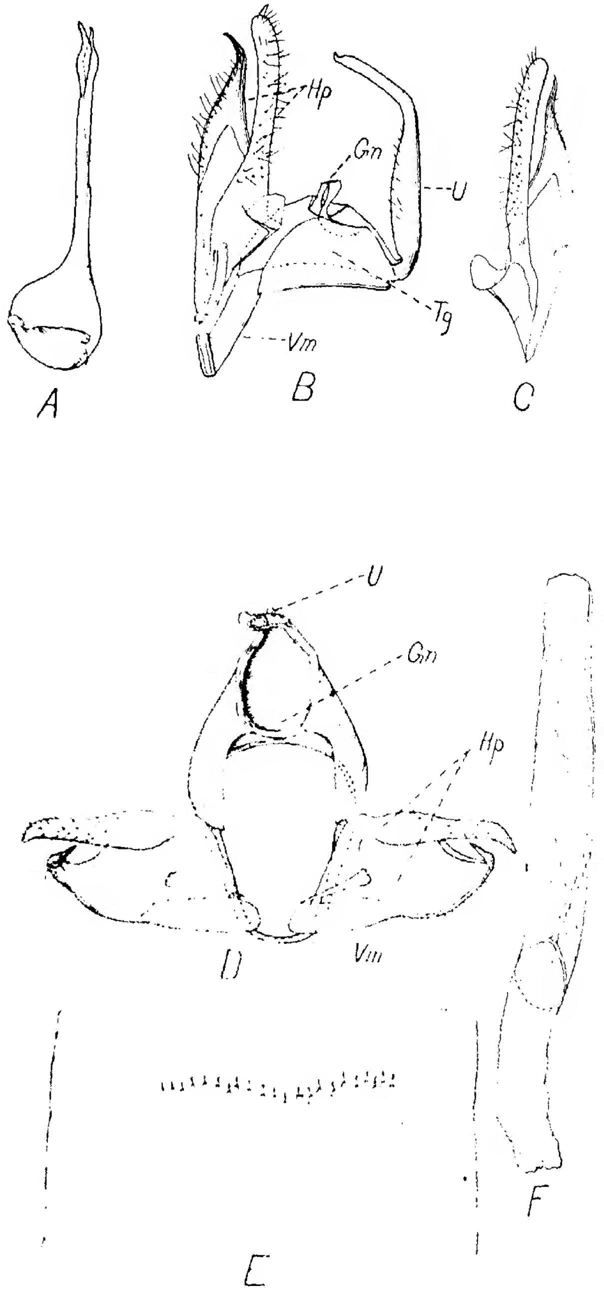
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PLATE 98

Male genitalia (Blastobasidae):

A.—*Zenodochium citricolella:* Aedoeagus.

B.—*Z. citricolella:* Lateral view of male genitalia, right harpe and aedoeagus omitted.

C.—*Z. citricolella:* Right harpe.

D.—*Holcocera ochrocephala:* Ventral view of male genitalia, spread, aedoeagus omitted.

E.—*H. ochrocephala:* Dorsum of an abdominal segment showing transverse row of spines.

F.—*H. ochrocephala:* Aedoeagus and penis.

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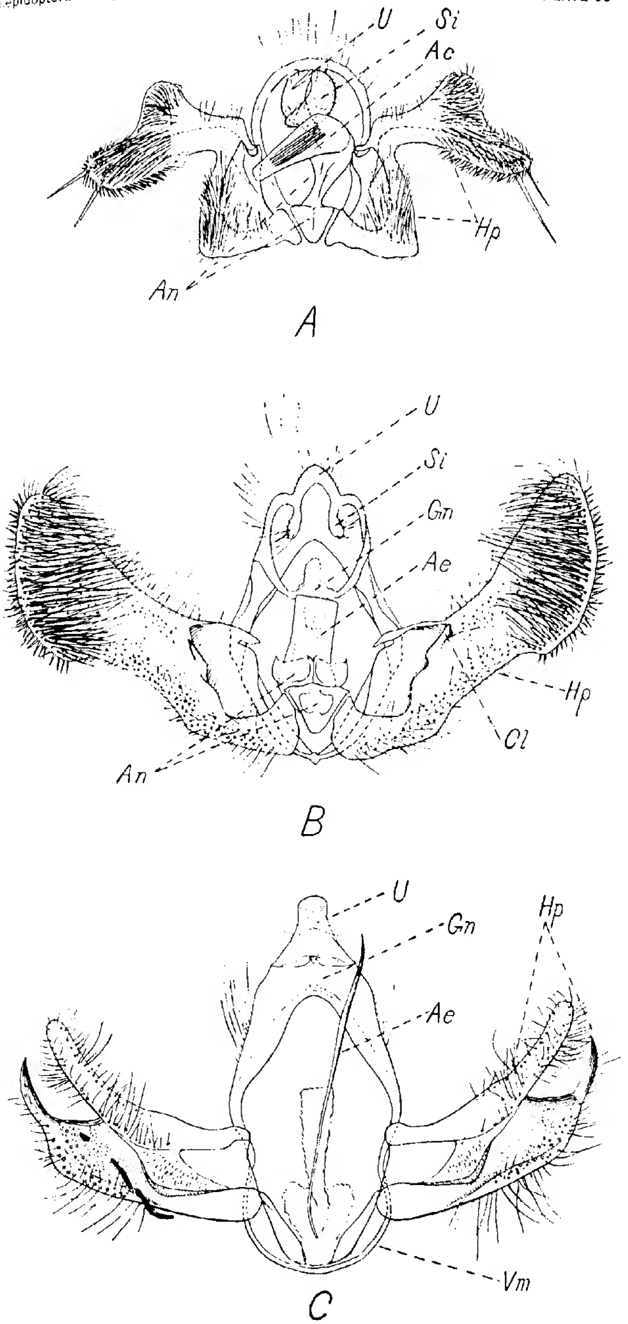
PLATE 99

Male genitalia (Olethreutidae and Blastobasidae):

A.—*Crocidosema plebeiana:* Ventral view of male genitalia, spread.
B.—*Eucosma discretivana* (type): Ventral view of male genitalia, spread.
C.—*Holcocera confamulella* (type): Ventral view of male genitalia, spread.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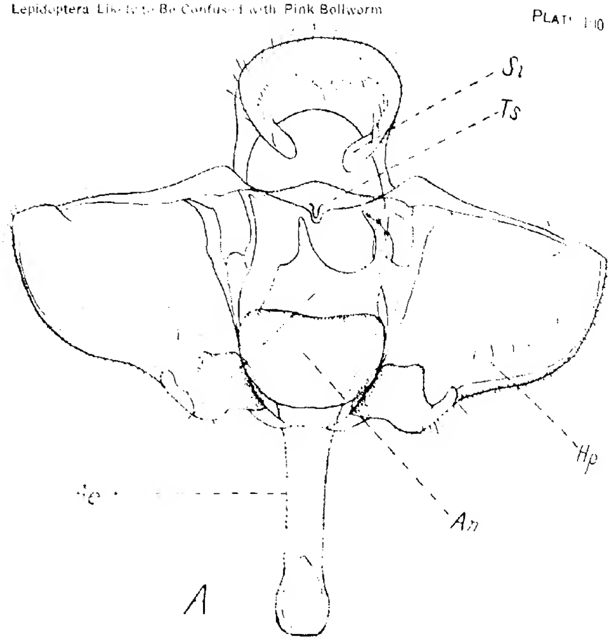

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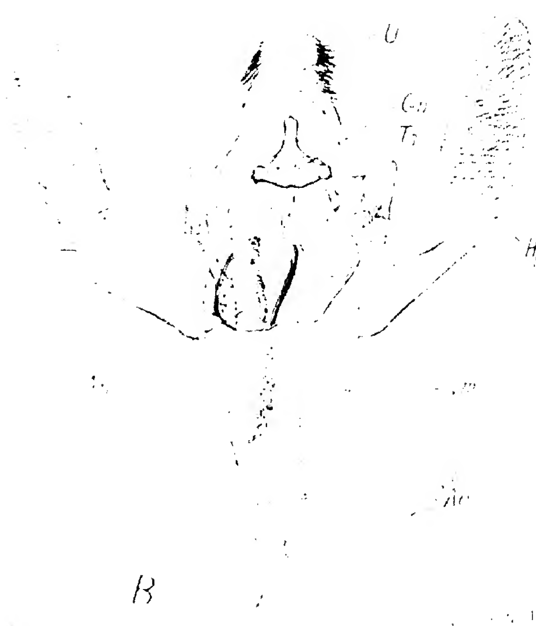

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PLATE 100

Male genitalia (Phaloniidae and Pyralidae):

A.—*Phalonia cephalanthana* (type): Ventral view of male genitalia, spread.
B.—*Homoeosoma electellum:* Ventral view of male genitalia, spread.

PLATE 101

Larval structures:

A.—*Pectinophora gossypiella:* Head capsule, dorsal view, showing arrangement of setæ.

B.—*P. gossypiella:* Head capsule, lateral view, showing arrangement of setæ.

C.—*Dicymolomia julianalis:* Head capsule, dorsal view, showing arrangement of setæ.

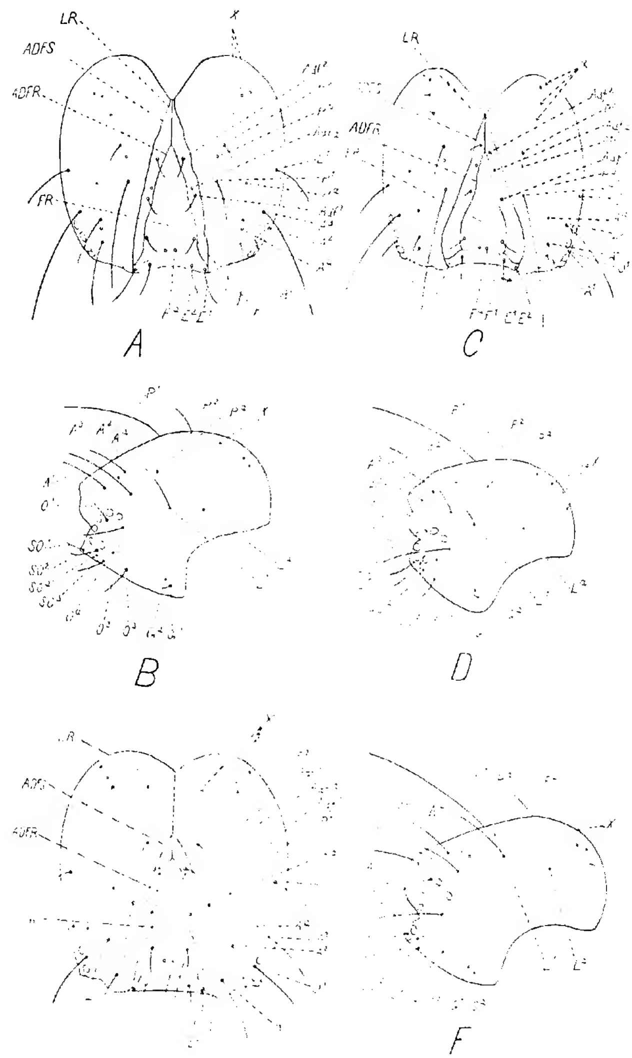
D.—*D. julianalis:* Head capsule, lateral view, showing arrangement of setæ.

E.—*Meskea dyspteraria:* Head capsule, dorsal view, showing arrangement of setæ.

F.—*M. dyspteraria:* Head capsule, lateral view, showing arrangement of setæ.

Explanation of symbols applied to larvæ on Plates 101–106.

A^1, A^2, A^3, A^a=anterior setæ and puncture of epicranium.
Adf^1, Adf^2, Adf^a=adfrontal setæ and puncture of epicranium.
ADFR=adfrontal ridge of frons.
ADFS=adfrontal suture.
AF=anal fork.
E^1, E^2=epistomal setæ.
F^1, F^a=frontal seta and puncture.
FR=frons.
G^1, G^a=genal seta and puncture of epicranium.
L^1, L^a=lateral seta and puncture of epicranium.
LR=longitudinal ridge of frons.
O^1, O^2, O^3, O^a=ocellar setæ and puncture of epicranium.
P^1, P^2, P^a, P^b=posterior setæ and punctures of epicranium.
SMp=platelike chitinization on submentum.
SO^1, SO^2, SO^3, SO^a=subocellar setæ and puncture of epicranium.
X=Ultraposterior setæ and punctures of epicranium.


LR
ADFS
ADFR
FR
X
A
C
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D
F

PLATE [illegible]2

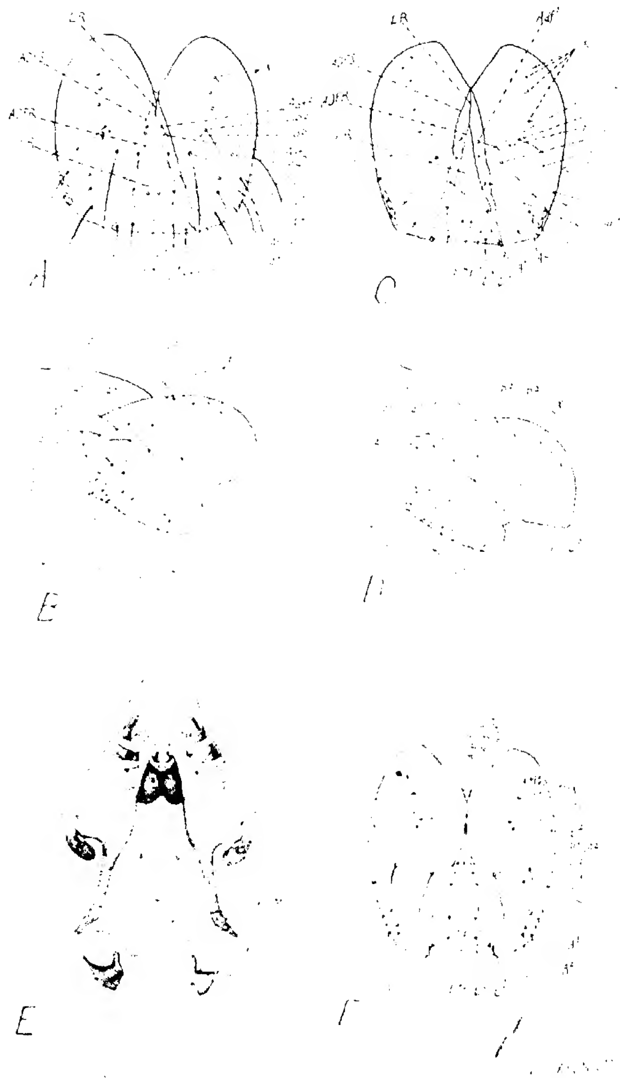


PLATE 102

Larval structures:

A.—*Pyroderces rileyi:* Head capsule, dorsal view, showing arrangement of setæ.
B.—*P. rileyi:* Head capsule, lateral view, showing arrangement of setæ.
C.—*Crocidosema plebeiana:* Head capsule, dorsal view, showing arrangement of setæ.
D.—*C. plebeiana:* Head capsule, lateral view, showing arrangement of setæ.
E.—*Zenodochium citricolella:* Labium and maxillæ.
F.—*Isophrictis similiella:* Head capsule, dorsal view, showing arrangement of setæ.

PLATE 103

Larval structures:

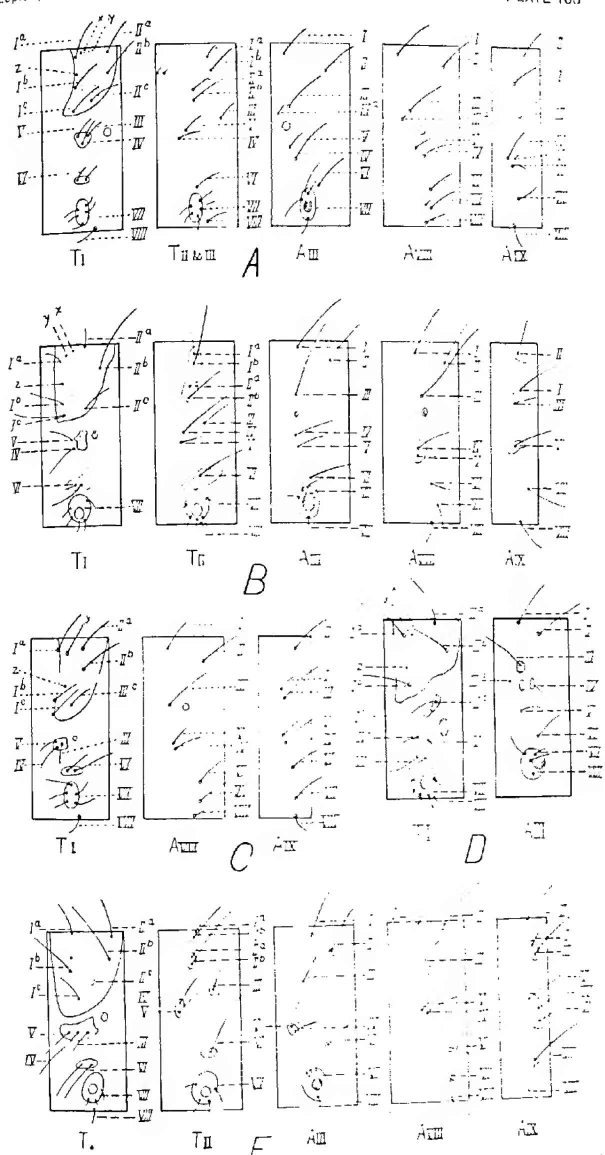
A.—*Pectinophora gossypiella:* Setal maps of first and second thoracic and third, eighth, and ninth abdominal segments.

B.—*Dicymolomia julianalis:* Setal maps of first and second thoracic and third, eighth, and ninth abdominal segments.

C.—*Pyroderces rileyi:* Setal maps of first thoracic and eighth and ninth abdominal segments.

D.—*Heliothis obsoleta:* Setal maps of first thoracic and third abdominal segments.

E.—*Crocidosema plebeiana:* Setal maps of first and second thoracic and third, eighth, and ninth abdominal segments.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B
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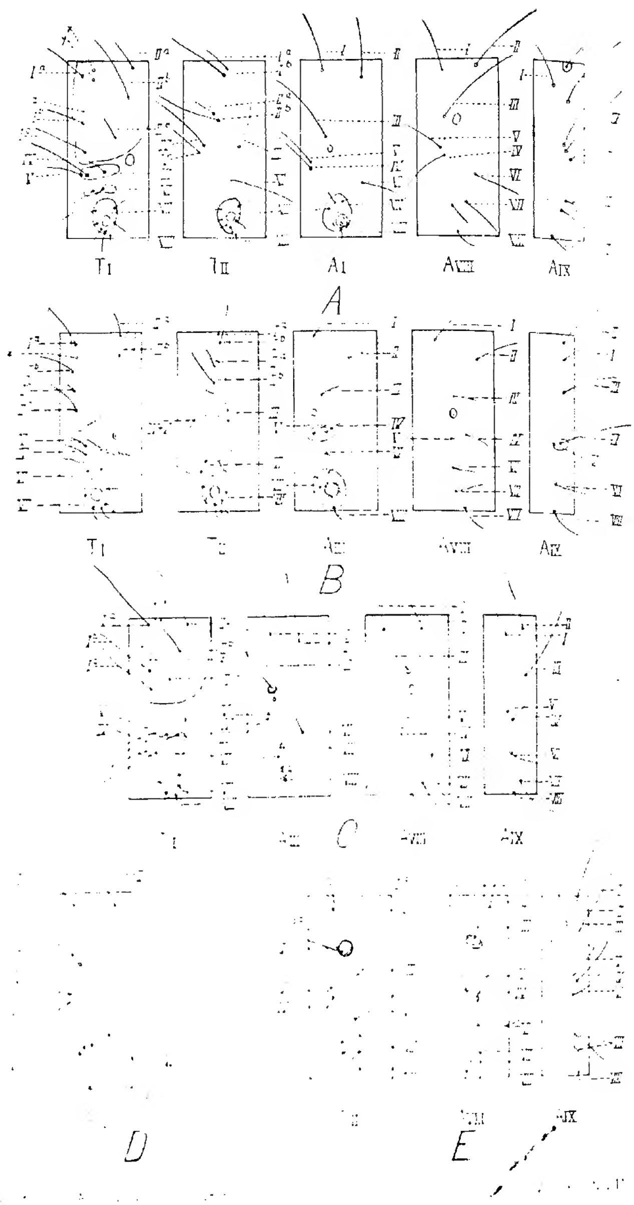


PLATE 104

Larval structures:

A.—*Platynota rostrana:* Setal maps of first and second thoracic and third, eighth, and ninth abdominal segments.

B.—*Meskea dyspteraria:* Setal maps of first and second thoracic and third, eighth, and ninth abdominal segments.

C.—*Zenodochium citricolella:* Setal maps of first thoracic and third, eighth, and ninth abdominal segments.

D.—*Aedemoses haesitans:* Setal map of third abdominal segment.

E.—*Moodna ostrinella:* Setal maps of second thoracic and eighth and ninth abdominal segments.

PLATE 105

Larval structures:

A.—*Platynota rostrana:* Setal maps of eighth and ninth abdominal segments, dorsal view.

B.—*Eucosma helianthana:* Setal maps of eighth and ninth abdominal segments, dorsal view.

C.—*Pectinophora gossypiella:* Setal maps of eighth and ninth abdominal segments, dorsal view.

D.—*Pyroderces rileyi:* Setal maps of eighth and ninth abdominal segments, dorsal view.

E.—*Pectinophora gossypiella:* Prothorax, ventral view, showing position of legs.

F.—*Telphusa mariona:* Ventro-caudal view of tenth abdominal segment, showing anal fork.

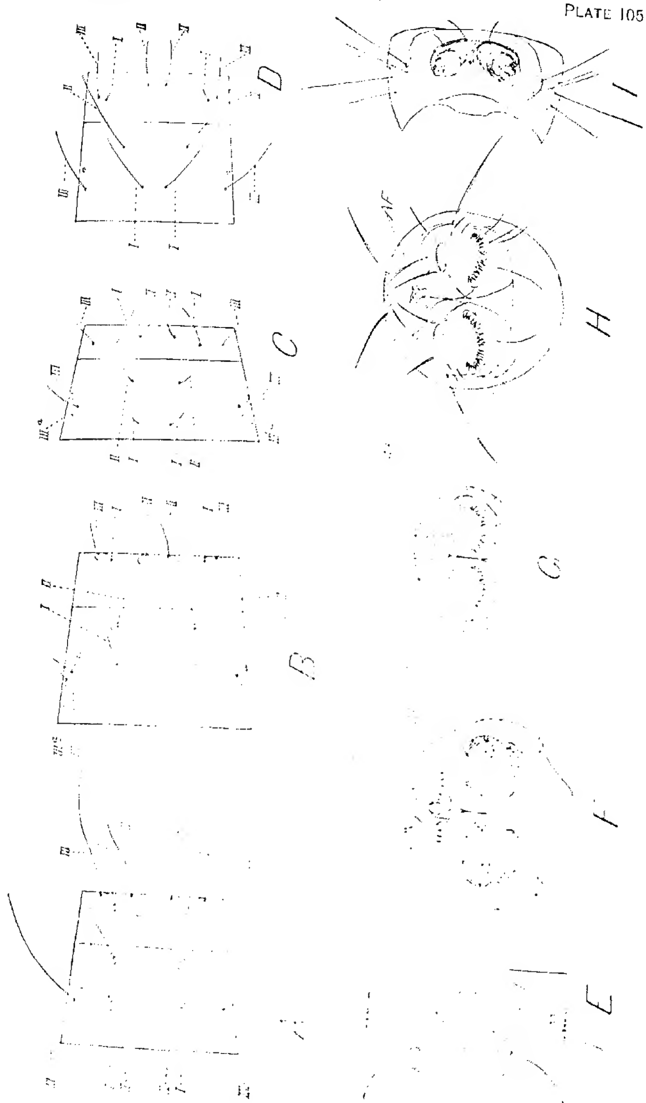
G.—*Crocidosema plebeiana:* Ventro-caudal view of tenth abdominal segment, showing anal fork.

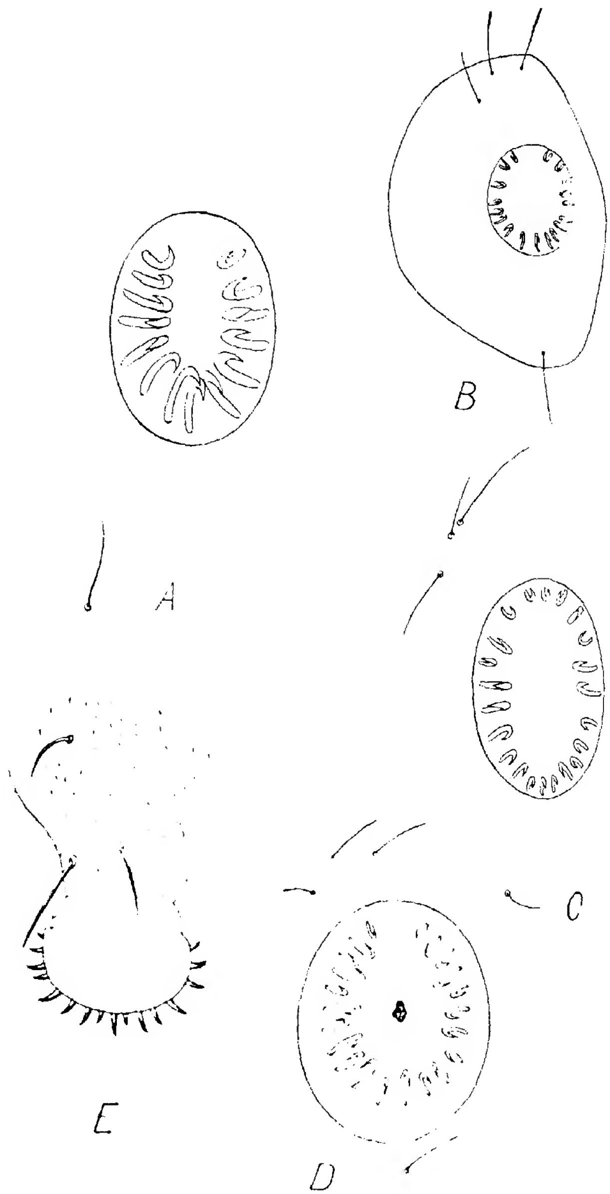
H.—*Gelechia neotrophella:* Ventro-caudal view of tenth abdominal segment, showing anal fork.

I.—*Zenodochium citricolella:* Prothorax, ventral view, showing position of legs.

tera Likely to Be Confused with Pink Bollworm

PLATE 105





A
B
C
D
E

PLATE 106

Larval structures:

A.—*Pectinophora gossypiella:* Crochet arrangement of abdominal prolegs.
B.—*Crocidosema plebeiana:* Crochet arrangement of abdominal prolegs.
C.—*Pyroderces rileyi:* Crochet arrangement of abdominal prolegs.
D.—*Dicymolomia julianalis:* Crochet arrangement of abdominal proleg.
E.—*Heliothis obsoleta:* Crochet arrangement of abdominal proleg.

PLATE 107

Pupal structures:

A.—*Pectinophora gossypiella:* Ventral view of pupa.

B.—*Pectinophora gossypiella:* Caudal end of pupa, lateral view.

C.—*Pectinophora gossypiella:* Mature pupa, ventral view, shaded to show eyes of imago visible through pupal skin and characteristic pubescence of the pupa.

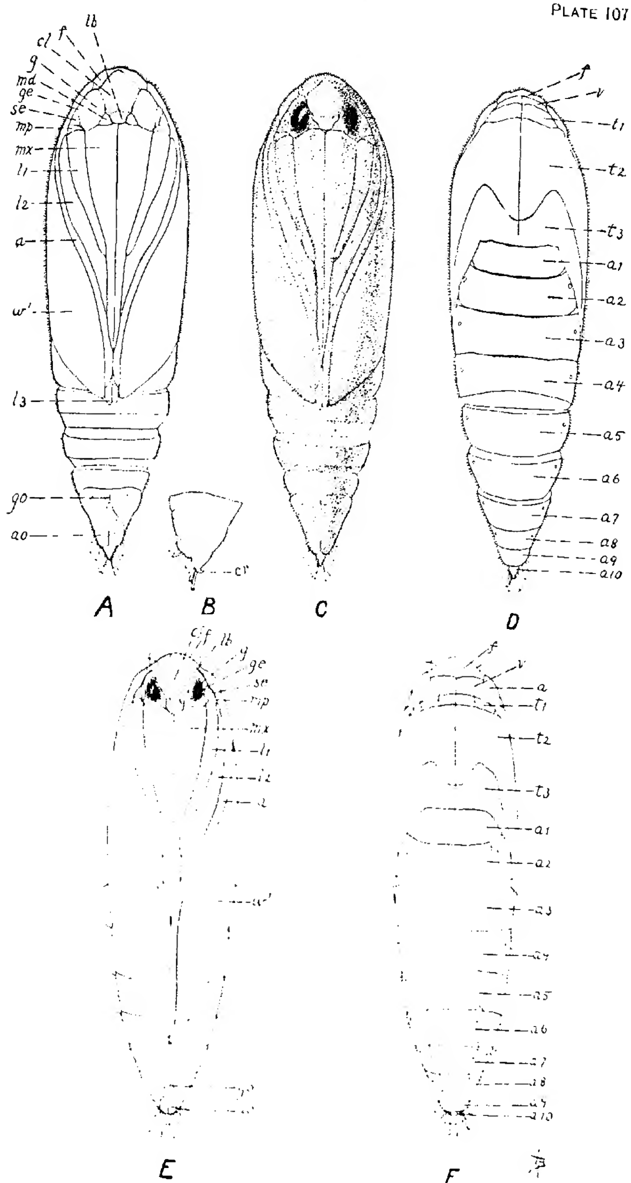
D.—*Pectinophora gossypiella:* Dorsal view of pupa.

E.—*Pyroderces rileyi:* Ventral view of pupa.

F.—*Pyroderces rileyi.* Dorsal view of pupa.

Explanation of symbols applied to pupæ on Plates 107–109.

a=antenna.
a^1 to a^{10}=abdominal segments 1 to 10.
ao=anal opening.
cl=clypeus.
cr=cremaster.
f=front.
f^1=femora of prothoracic leg.
fcs=fronto-clypeal suture.
g=gena.
ge=glazed eye.
go=genital opening.
lb=labrum.
l^1=prothoracic leg.
l^2=mesothoracic leg.
l^3=metathoracic leg.
lp=labial palpi.
md=mandible.
mp=maxillary palpus.
mx=maxilla.
pf=pilifer.
se=sculptured eyepiece.
t^1=prothorax.
t^2=mesothorax.
t^3=metathorax.
v=vertex.
w^1=mesothoracic wing.


lb
cl
f
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md
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mx
l1
l2
a
w'
l3
go
ao
cr
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t3
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C
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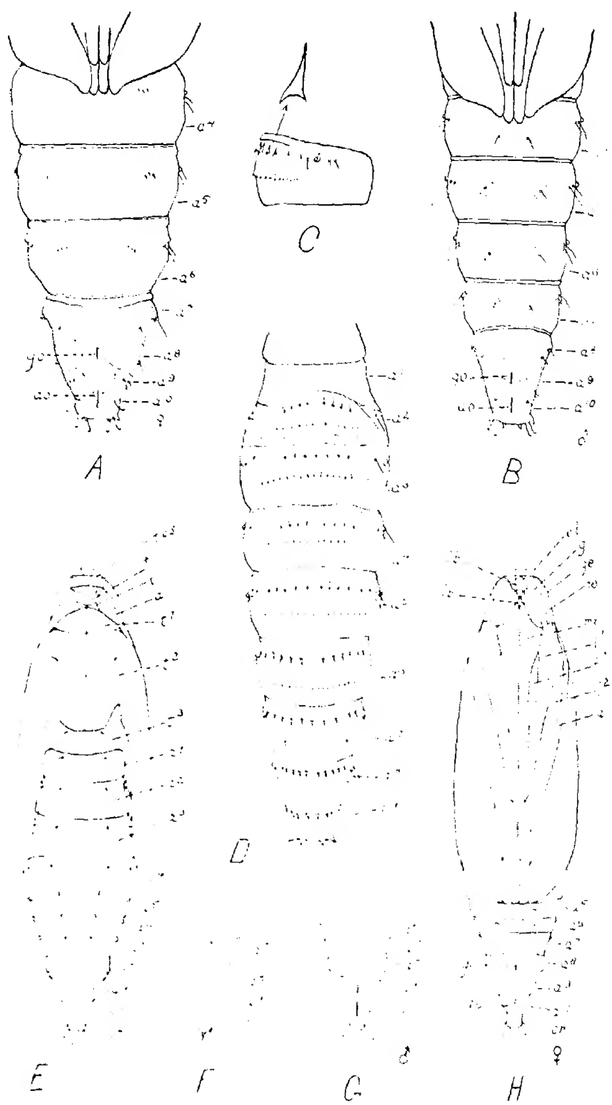

A
B
C
D
E
F
G
H

PLATE 108

Pupal structures:

A.—*Crocidosema plebeiana:* Abdomen of female pupa, ventral view.

B.—*C. plebeiana:* Abdomen of male pupa, ventral view.

C.—*C. plebeiana:* Lateral view of an abdominal segment, showing arrangement and character of dorsal spines; one spine greatly enlarged to show shape.

D.—*C. plebeiana:* Abdomen of pupa, dorsal view.

E.—*Dicymolomia julianalis:* Dorsal view of pupa.

F.—*D. julianalis:* Caudal end of pupa, lateral view.

G.—*D. julianalis:* Caudal end of male pupa, ventral view.

H.—*D. julianalis:* Ventral view of female pupa.

PLATE 109

Pupal structures:

A.—*Meskea dyspteraria:* Caudal end of female pupa, lateral view.

B.—*M. dyspteraria:* Abdomen of female pupa, ventral view.

C.—*M. dyspteraria:* Male pupa, dorsal view.

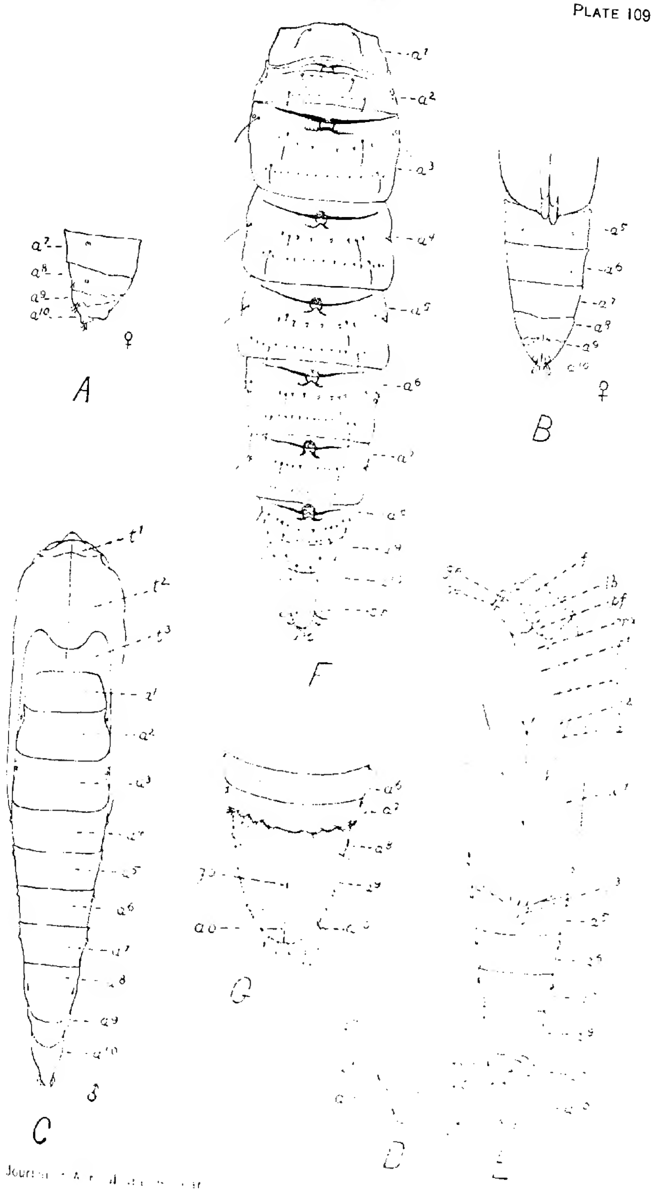
D.—*M. dyspteraria:* Caudal end of male pupa, lateral view.

E.—*M. dyspteraria:* Male pupa, ventral view.

F.—*Amorbia emigratella:* Abdomen of pupa, dorsal view.

G.—*Telphusa mariona:* Caudal end of pupa, ventral view, showing peculiarly scalloped and fringed caudal margin of seventh abdominal segment.

PLATE 109



BIOLOGY OF THE SMARTWEED BORER, PYRAUSTA AINSLIEI HEINRICH[1]

By GEORGE G. AINSLIE, *Entomological Assistant*, and W. B. CARTWRIGHT, *Scientific Assistant, Cereal and Forage Insect Investigations, Bureau of Entomology, United States Department of Agriculture*

INTRODUCTION

The attention of the senior author was first called to the smartweed borer in 1912, when hibernating larvæ were found in cornstalks at Franklin, Tenn. The economic status of this insect was undetermined at that time, but field and rearing records made in Tennessee and neighboring States since then have indicated that it is of no importance as a pest. At present, however, it is of considerable interest because of its similarity, both in habits and appearance, to the European corn borer (*Pyrausta nubilalis* Hübner). Until recently, also, it has been confused with another similar species, *P. penitalis* Grote, which feeds on lotus; and the purpose, in part, of this paper is to rectify this error.

Although Dr. E. Mosher (*7, p. 264*)[2] recorded differences of structure and the present authors found distinct variations in habit between the insect under discussion and the true *Pyrausta penitalis*, the former was first definitely recognized as an undescribed species by Mr. Carl Heinrich (*6*) of the Bureau of Entomology. Mr. Heinrich gives in detail the morphological characters separating the species *nubilalis*, *penitalis*, and *ainsliei* in all stages. Chittenden (*1*) has well summarized all the available records of the smartweed and lotus borers, although he was not aware that two species were included.

DISTRIBUTION AND HOST PLANTS

The smartweed borer is known to occur in Massachusetts, New York, Pennsylvania, Ohio, and Illinois; and the writers have taken it at numerous points in Tennessee and Kentucky and at Clemson College, S. C. *Polygonum pennsylvanicum*, its principal food plant, occurs throughout the eastern half of the United States, and it is likely that the distribution of the borer is coextensive therewith.

The plants in which the larvæ are found must be divided into two groups, namely, food plants proper and shelter plants.

---

[1] In recent papers by Flint and Malloch (*3, 4*), the name *Pyrausta obumbratalis* Lederer (misspelled *obumbratilis*) is used for this species. While it is possible that *ainsliei* will prove to be a synonym of *obumbratalis*, it seems inadvisable at this time to use this latter name for this species, for, until Lederer's type can be examined and its exact identity and relation to the other species under discussion determined, its use will simply add confusion to a matter which seems in a fair way to be solved.

[2] Reference is made by number (italic) to "Literature cited," p. 844.

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Key No. K-93

FOOD PLANTS

Riley (according to Chittenden, *1, p. 454*), who first noted what was probably this species, found larvæ in stems of *Polygonum incarnatum;* and Hart (*5, p. 182*) mentions that it has been reared from the same species at Urbana, Ill. Chittenden states that there is a moth in the National Museum reared from stems of *Polygonum hydropiperoides*. The foregoing references occur under the name of *Pyrausta penitalis*, but relate without doubt to *Pyrausta ainsliei*. After investigating the matter in New York, Dr. E. P. Felt writes that in his opinion—

Pyrausta ainsliei occurs very commonly in *Polygonum pennsylvanicum* in this section [New York] and much more rarely in *P. lapathifolium*.

Mr. D. J. Caffrey writes that *Pyrausta ainsliei* has been reared from *Polygonum persicaria* in Massachusetts.

The work of the present authors indicates very clearly that south of the Ohio River, at least, *Pyrausta ainsliei* breeds only in *Polygonum pennsylvanicum*. Despite the most careful and persistent search they have failed to find either larvæ or eggs, or any trace of them, on plants of any other species even though growing in the immediate vicinity of *Polygonum pennsylvanicum* and often in the same clump. The species of the genus Polygonum are often confused, and determinations of plants for entomological purposes are so often made carelessly or from insufficient material that further work appears necessary in order that the occurrence of this borer in species other than *Polygonum pennsylvanicum* may be verified. As *Polygonum incarnatum* is now considered a synonym of *Polygonum lapathifolium* the following are here listed as reported natural food plants of *Pyrausta ainsliei: Polygonum pennsylvanicum*, *Polygonum lapathifolium*, *Polygonum hydropiperoides*, and *Polygonum persicaria*.

It should be stated that although never found on them in the field, larvæ have been reared from eggs to full-size caterpillars on leaves of curled dock (*Rumex crispus*) and buckwheat (*Fagopyrum fagopyrum*), both of which are close relatives of Polygonum. Leaves of all common weeds and plants were offered to the larvæ, but in every case except the two mentioned above they were either refused or only slightly gnawed. On leaves of lotus (*Nelumbo lutea*) the larvæ in several experiments starved to death after merely pitting the leaf surface. Mr. Heinrich's statement (*6, p. 175*) that we have reared these larvæ to maturity on *N. lutea* is an error.

SHELTER PLANTS

The other group, shelter plants, includes all plants the stems of which are entered by larvæ seeking winter quarters. The list of such plants will eventually contain practically all the pithy stemmed weeds and plants the bark of which is not too dense to permit the entrance of the larvæ. Some of the larvæ remain in the stems of smartweed, but for some

obscure reason many leave their food plant and seek entrance to anything that will give them dry quarters through the winter. The plants in which larvæ have been found by the authors are as follows: Corn (*Zea mays*), ragweeds (*Ambrosia trifida* and *Ambrosia artemisiaefolia*), cocklebur (*Xanthium communis*), goldenrod (*Solidago* spp.), aster (*Aster* spp.), timothy (*Phleum pratense*), cattail (*Typha latifolia*), beggartick (*Bidens bipinnata* and *B. frondosa*), and numerous other wild plant stems not in condition for determination. Dr. Felt adds *Brassica arvensis* and Chittenden (*1*) lists raspberry stems, to which the larvæ gained entrance through the cut ends. *Eupatorium* sp., in which larvæ were found in Missouri according to Chittenden, is also undoubtedly a shelter plant. Aside from *Polygonum* spp. the foregoing plants are in no sense food plants. The larvæ burrow the stems enough to construct a cavity sufficiently large to contain them; and even in this process, as the authors have observed, they do not swallow the plant tissue but eject it from the mouth. It is this habit of seeking shelter wherever it may be found, especially in cornstalks, that seems likely to lead to some confusion, for the larvæ are so similar to those of *Pyrausta nubilalis*, the European corn borer, that without careful laboratory study the two can not be differentiated.

SEASONAL HISTORY AND HABITS

In Tennessee there are two generations of the smartweed borer each year. Adults reared at Knoxville emerged from May 26 to October 30 with two well-defined periods of maximum abundance, the first from June 20 to July 5 and the second from August 18 to 30. Moths emerging in June at once oviposit, and the resulting larvæ complete their growth early in August and immediately pupate in their larval burrows in the smartweed stems. The moths emerge later in the same month and give rise to the second generation of larvæ, which reach full growth before winter and without further feeding remain in the food or shelter plants unchanged until they pupate in May and June of the following year.

Very few published data are available. Hart (*5, p. 182*) states that moths (probably of this species, as there is no Nelumbo near Urbana) were taken at light at Urbana, Ill., from May 19 to August 6, and that a single moth was reared July 1. In Missouri moths issued from smartweed from May 29 to June 6, and others are labeled October 9. Although scattering data on this species are included in his paper, Chittenden's conclusions do not agree with the actual life history as the authors have found it, and his statements must be taken, in the main, to apply to *Pyrausta penitalis*.

In a reared series of larvæ from eggs hatching August 16 a number of moths emerged October 13 and 15. This is difficult to explain except on the ground of abnormal conditions, for it does not seem possible that in nature moths emerging so late could produce another generation, and

under natural conditions neither pupæ nor moths have been found at this time of the year.

HABITS OF THE MOTHS

The moths frequent low, moist situations where the food plants grow normally. During the day they rest on or under the leaves and when disturbed make low direct or circuitous flights within the bounds of their haunts.

THE EGGS

Eggs have been taken many times in the field, but oviposition has not been observed. It doubtless occurs at dusk or during the night, and possibly on cloudy days, as the moths seem active only at such times. The eggs are laid in small patches or often in rows, with the individual eggs overlapping shingle fashion, on the underside of the leaves, more often those near the tips of the branches, and either on the leaf blade proper or close beside the midrib in the angle between it and the blade.

Near Union City, Tenn., on August 8, 1919, the senior author found an isolated clump of six plants of *Polygonum pennsylvanicum.* Thirty egg masses were found on these plants, all but one or two close beside the midrib on the under surface of the leaf. In three instances there were more than one mass on a leaf, but the difference in the stage of development clearly showed that they had been laid at different times. The number of eggs per mass varied from 4 to 16, the average being 9.3. In another collection of 17 egg masses made at Knoxville, August 12, the number of eggs varied from 7 to 14, with an average of 9.47 per mass.

As the egg has not heretofore been described, its description follows:

EGG.—Flat, thin, scalelike, laid in flat masses or rows of from 4 to 16, shingle fashion, each egg about half overlapping its predecessor. The individual egg is broadly elliptic, sometimes almost circular in outline, about 1.213 mm. long and 0.886 mm. broad. Chorion evenly reticulated all over with a close network of very fine but sharply elevated lines. Pale watery-greenish in color, nearly transparent when first laid, soon becoming more opaque, after which the embryo takes shape as a darker green, more transparent object in the center. No marked change then occurs until just before hatching, when the eyes and the mandibles darken, the color spreading to the whole head which becomes brown and plainly visible and appears detached because of the paleness and practical invisibility of the larval body which lies bent around the periphery.

The period of incubation in June and July is six days, in late August five days.

HABITS OF THE LARVÆ

Upon hatching, the young larvæ at once enter the stem near the tip of a branch, choosing the base of a petiole for their point of attack. That they are somewhat gregarious at this stage is shown by the fact that all the larvæ hatching from one egg mass usually enter the stem at the same point, which may be several inches from the egg mass. Thus in the first

and second instars burrows are often found containing a number of larvæ. Their work very quickly results in the wilting of the tender tips above the point of attack, and these drooping tips soon become to the observer an almost certain indication of the presence of the young larvæ. As soon as the food supply here is exhausted the larvæ desert this portion of the stem and scatter, each reentering at another point to make a burrow of its own, and thereafter only one larva is found in a burrow, although it often happens in a thickly infested stem that these burrows are practically continuous. The stems of *Polygonum pennsylvanicum* are thick-walled and succulent, with only a very small central cavity. The larvæ cut into this cavity, almost invariably entering at the swollen node just below the base of the ocrea, and consume the succulent tissue, leaving only the very thin, fibrous, outer bark. They do not hesitate to abandon a burrow and seek another location whenever the food supply fails. The larger stems are attacked first, but later the branches are utilized, often those so small that the larvæ can scarcely crowd into them. The burrows are kept clean, all excrement being disposed of through the entrance, which is left open, although with the growth of the plant it often partially heals.

Larvæ of the first generation make no effort to leave the smartweed stems but pupate in them as soon as fully fed. Those of the second generation attack the plants in the same way and feed as did their progenitors until they are fully grown. This stage is reached about the last of August, and thereupon many of the larvæ abandon their host plant and seek shelter elsewhere. Those entering cornstalks have been particularly noted. Neither thoroughly dry nor green stalks suit them as well as those of intermediate condition. They enter preferably under a leaf sheath or behind an ear. Their presence is indicated by the fluffy white pith showered from the entrance hole upon the leaves below. The entrance hole is perfectly round and clean-cut, and the burrow within is of equal diameter, 3 to 3.5 mm., and is kept clean and free of all cuttings and excrement. It turns downward from the entrance and is from 1 to 4 inches long. Early in October the larva closes the entrance with a drum-tight sheet of silk, quite effectively camouflaged by the incorporation of a few brownish particles of the chewed bark.

As far as determined the larvæ are not torpid during the period of hibernation. Repeated collections of larvæ in the field during the winter show them always quick to respond when disturbed. There is no evidence that they consume any food before pupation after leaving their food plants in the fall. In making their winter burrows in the shelter plants they do not swallow the tissue but discharge it from the mouth in sawdust-like particles.

No very definite cocoon is constructed by either generation. In smartweed the burrow is lightly plugged above and below the pupa

with pith particles interwoven with silk, and sometimes in the larger cavities a light cocoon is constructed, hardly more than a network of silk fibers. The burrow formed in smartweed by the larvæ of the first generation runs upward from the entrance; and the pupal chamber, in which the pupa lies head downward, is 1 or 2 inches above the exit hole. The emerging moth breaks the partition and leaves the pupal envelope in the chamber. In corn the cocoon is even less elaborate, and the most evident difference is that the pupa lies head upward in the burrow.

REARING RECORDS

Eggs were easily obtained from moths collected in the field and confined in lantern-chimney cages with a potted smartweed or in 1-ounce tin boxes containing a leaf of the same plant. The eggs hatched normally, and the young larvæ were transferred singly to 1-ounce tin boxes for rearing. The larvæ while young thrived on smartweed leaves, but in later stages they preferred the stems.

Table I contains the condensed data obtained from a series of larvæ hatching from eggs laid July 21 and from miscellaneous rearings from partly grown larvæ taken in the field.

TABLE I.—*Length, in days, of instars and stages of Pyrausta ainsliei*

Stage.	Maximum.	Minimum.	Average.	Number averaged.
Egg	6	6	6	....
Larva:				
Instar I	4	3	3.27	15
II	6	3	4.64	14
III	7	4	5.22	14
IV	7	4	5.55	9
V	12	3	7.66	6
VI	28	18	23.67	3
Pupa	16	12	13.33	3
Total	....	....	69.34	....

Table II contains similar data obtained from a series of 60 larvæ reared individually from eggs hatching August 18.

TABLE II.—*Length, in days, of instars and stages of Pyrausta ainsliei*

Stage.	Maximum.	Minimum.	Average.	Number averaged.
Egg	5	5	5	....
Larva:				
Instar I	2	2	2	60
II	8	3	4.90	50
III	9	3	5.30	43
IV	18	5	10.31	32
V	37	20	24.66	12
Pupa	17	6	12.20	5
Total	....	....	64.37	....

It will be noted that in Table II only five instars are listed, but that the fourth is nearly equal to the combined length of the fourth and fifth of Table I. It is possible that an error has been made here, but the notes are clear. The matter will be reviewed another year.

Chittenden mentions 11 and 17 days, respectively, as the lengths of the pupal stage of two specimens reared by him from cornstalks from Kansas.

NATURAL CONTROL

The smartweed borer varies greatly in abundance from year to year, and this seems to be due, in Tennessee at least, to variation in the abundance of its parasites. Here the most important of these appears to be *(Panzeria) Pyraustomyia penitalis* Coq., as over 40 per cent of the larvæ taken in the field at Knoxville for rearing were killed by it. Chittenden notes that this same species also killed more than 50 per cent of the larvæ taken by him in raspberry stems. The host grows normally and reaches its final instar before the maggot emerges. In its last instar the host becomes sickly and inactive, paler than normal, and finally incloses itself in a loose webbing. The parasite maggot emerges and pupates beside or partly within the remains of its host, often closely crowded into the cavity with them. In the overwintering larvæ the parasite remains within its host's body until spring and about the middle of May emerges and pupates in the normal manner. The pupal period for the fly varies from 13 to 16 days, being more often the latter. The flies that have been reared by the authors have emerged during two distinct periods—May 30 to June 10 and August 18 to September 12—coinciding closely with the normal dates for the emergence of the moths. This leads to the assumption that the flies must attack the host larvæ during their early instars.

Coquillett (*2, p. 15, 17, 19, 27*) records three other tachinid flies (two of them quoted from Townsend (*9, p. 467*)) as reared from "*Pyrausta penitalis*"—namely, *Exorista vulgaris* Fall., *Hypostena variabilis* Coq., and *Phorocera comstocki* Will., but the information given is not sufficient to determine whether they are parasites of *Pyrausta ainsliei* or of the true *Pyrausta penitalis*.

Cremastus facilis (Cresson) was reared by Chittenden.

Three apparently distinct hymenopterous parasites have been found by the writers. One of these had spun a white cocoon and attached it to the remains of a host larva in its burrow. The second species was represented by small grubs which filled a dead larva. These grubs later made gray cocoons, only one of which developed. Two grubs of the third species were found attached externally to a larva. One of the grubs developed to an adult and was determined by Gahan as *Microbracon* sp., a male, and not specifically determinable. The authors have not received determinations of the other material.

Aside from true parasites, a coleopterous larva found preying on a larva of *Pyrausta ainsliei* was reared and determined by Schwarz as *Callida decora* Fab. Larvæ of *Chauliognathus pennsylvanicus* DeGeer are often found in the burrows and doubtless make way with some of the borers. In two instances they have been found feeding upon the contents of the puparia in the stems. Forficulids have been found in the burrows, but they probably act merely as scavengers.

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EFFECTS OF X-RAYS ON TRICHINÆ

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INTRODUCTION

The object of the experiments that are described in this paper was to determine whether X-rays exert deleterious influences on trichinæ (*Trichinella spiralis*), with a view to the practical application of X-ray radiation to the destruction of trichinæ in pork. These experiments were performed with the cooperation of a commercial firm that was operating X-ray machines in Florida. The experiments were planned and the details arranged by B. H. Ransom, Chief of the Zoological Division of the Bureau of Animal Industry, in consultation with the roentgenologist of the firm in question. The former supervised the tests made by the writer to determine the effects of the X-ray treatment upon the trichinæ, while the latter carried out the portions of the investigations relating to the X-ray treatment, calculations of the X-ray dosages used, etc.

The number of experiments that have been performed are insufficient to warrant any definite conclusions concerning the feasibility of applying X-ray radiation to the destruction of trichinæ in pork in routine packing-house procedure. Aside from the fact that the expense involved may render that procedure impracticable, much more experimental work than is presented in this paper would be required to demonstrate whether X-ray treatment could be depended upon to destroy trichinæ. The experimental data at hand are of interest from a general scientific viewpoint, however, and it is from that point of view that they are presented.

In a discussion of the effects of X-rays on the flour beetle (*Tribolium confusum*), Davey, [1] referring to his own work and the work of various other investigators, states:

> X-rays may act upon an organism (or on a single type of cell in that organism) in one of three ways: (1) to produce a stimulation; (2) to produce a destructive effect which takes place only after a certain latent interval; (3) to produce an instant destructive effect.

That the effects of X-rays on trichinæ so far as they are injurious become evident only after the parasites are subjected to influences that stimulate them to growth and development, or, in other words, after they reach the intestine of a host in which they normally attain sexual maturity,

[1] Davey, Wheeler P. The effect of x-rays on the length of life of tribolium confusum. *In* Jour. Exp. Zool., v. 22, No. 3, p. 575–576. 1917.

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and accordingly, that X-rays act on trichinæ in the second of the three ways mentioned above, is indicated by the results of the experiments recorded here.

METHODS OF EXPERIMENT

The trichinous meat used in these tests was obtained from hogs (series I, II, III, and V) and guinea pigs (series IV). The animals were artificially infected by feeding them trichinous pork. The infested pork to be exposed to X-rays was obtained from hogs that were killed several months after artificial infection. Trichinous guinea-pig meat was obtained from animals kept about a month after artificial infection.

Trichinous pork was packed in wooden or cardboard boxes in Washington, forwarded to Florida, where the exposure to X-rays was made, and promptly returned to Washington, where it was fed to experimental animals in order to determine the effects of the exposure. In a few cases portions of the meat that had been exposed to X-rays were digested in an acidified solution of scale pepsin, the decapsuled larvæ were examined, and the results were compared with those of the feeding experiments. Infested guinea pigs were shipped alive to Florida about 30 days after artificial infection. The animals were killed with chloroform in Florida, the skins and viscera were removed, and the carcasses were placed in boxes, exposed to X-rays, and returned to Washington.

The feeding experiments were performed in Washington. A quantity of the treated meat was ground up in a meat chopper and fed to a number of rats and, in some cases, mice. Unless they died as a result of infection with trichinæ the animals were killed at various intervals and examined for evidence of infestation with trichinæ as noted in connection with each experiment. Controls on the meat from the same lots as those exposed to X-rays showed that in all cases in which it was possible to maintain controls the untreated meat contained viable trichinæ capable of normal development. In those cases in which the entire carcasses of trichinous guinea pigs were exposed to X-ray treatment it was of course not possible to maintain controls.

EXPERIMENTS

SERIES I

X-RAY DOSAGE.—The units of dosage used in this series of experiments are described by the roentgenologist under date of January 20, 1917, on which day the exposures to X-rays were probably made,[1] as follows:

> I adopted a purely arbitrary unit, 1,000 of which units are equivalent to a dosage received at a distance of 5 inches from the focal spot of a Coolidge tube with a current of 4.2 milliamperes and a pressure of 70 kilovolts across the tube terminals. Treatment continued for 42 minutes. In ordinary X-ray terms this is equivalent to 172 milliampere minutes with a 6½-inch gap and a 5-inch distance.

[1] The meat was received in Washington on January 22, and feeding experiments were begun on January 23.

EXPERIMENT 1.—Strength of dosage, 2,899 units.

Twelve rats and two mice were fed in this experiment.

Rats 1, 2, and 3 were fed on January 23. Rats 1 and 2 were chloroformed on January 26. No trichinæ were found in the intestines. Rat 3 died on February 23; diaphragm negative.

Rats 4 to 9, inclusive, were fed on January 25. Rat 4 was killed on January 26. Trichinæ were found in the intestine. The parasites were about ready to molt. They were somewhat paler than normal. Rat 5 was killed on January 27. No trichinæ were found in the intestine. No. 6 was killed on February 26; diaphragm negative. No. 7 was killed on March 12; diaphragm negative. No. 8 and 9 were killed on March 15; diaphragms negative.

Rats 10 to 12, inclusive, were fed on January 30. Rats 10 and 11 were killed on January 31. A few trichinæ were found in the intestines of each animal. The parasites showed evidences of growth. Most of them were dead, however, having undergone granular degeneration.

Rat 12 was killed on February 1. A few trichinæ were found attached to the mucosa of the intestine. These showed evidence of growth.

Two mice were fed some of the treated meat on January 29. Mouse 1 was killed on January 30. No trichinæ were found in the intestines. Mouse 2 was killed on the same date. A few trichinæ were found in the intestines. The parasites were dead but showed evidence of growth. No details of structure were made out because the parasites had undergone granular degeneration.

EXPERIMENT 2.—Strength of dosage, 966 units.

Nine rats were fed in this experiment. Rats 1 to 3 were fed on January 23. Rat 1 was killed on January 26. No trichinæ were found in the intestines. Rat 2 was killed on February 2. A few trichinæ, apparently fully grown, were found in the intestines. The parasites showed rather striking malformations, which were especially pronounced in the reproductive organs. The gonads were shrunken. The uterus of female specimens contained eggs, but the latter were full of minute granules. The receptaculum seminis, which in normal females is crowded with spermatozoa, was empty.

Rat 3 was killed on February 6. No trichinæ were found in the intestines.

Rats 4 to 9 were fed on January 25. Rat 4 was killed on January 27; intestines negative. Rat 5 was killed on February 1; a few trichinæ were found in the intestines. The parasites showed marked evidence of degeneration. The cuticle was wrinkled; internally numerous vacuoles were seen; the sex cells appeared undeveloped; the worms showed very feeble movements. No. 6 was killed on February 26; diaphragm negative. No. 8 and 9 were killed on March 15; diaphragms negative.

EXPERIMENT 3.—Strength of dosage, 191 units.

Six rats were fed in this experiment. Three rats were fed on January 25. Rat 1 was killed on January 26. Trichinæ were found in the intestine. The parasites appeared normal as to size and structure. Rat 2 was killed on January 29; trichinæ in intestines normal; uterus of females packed with embryos. No. 3 was killed on February 2. Numerous trichinæ were found in the intestines; apparently normal.

Three rats were fed on January 26. One rat died on February 6. Numerous larvæ were found in the fluid expressed from the diaphragm. Intestines showed numerous trichinæ. The second rat was killed on February 12. Numerous unencysted larvæ were found in the diaphragm. The third rat died on February 24. Numerous encysted trichinæ were found in the diaphragm.

EXPERIMENT 4.—Strength of dosage, 81 units.

Five rats were fed in this experiment. Rats were fed on January 23. Rat 1 was killed on January 26; numerous live trichinæ were found in the intestines. Rat 2 was killed on January 29; intestines negative. Rat 3 was killed on February 3; numerous live trichinæ in intestines. Rats 4 and 5 were killed on March 15; diaphragms heavily infested with trichinæ.

EXPERIMENT 5.—Strength of dosage, 35 units.

Five rats were fed in this experiment. Rats 1 and 2 were fed on January 23. Rat 1 was killed on January 26; numerous live trichinæ in intestines. Rat 2 was killed on January 27; results as in No. 1. Rats 3 to 5 were fed on January 29. Rat 3 died on February 5; numerous live trichinæ in intestines. Rat 4 died on February 24; diaphragm heavily infested with trichinæ. Rat 5 died March 2; results as in No. 4.

EXPERIMENT 6.—Dosage, 19 units.

Three rats were fed on January 23 with the meat treated in this experiment. Rat 1 was killed on January 26; intestines contained many live trichinæ. Rat 2 died on February 12; diaphragm not infested. Rat 3 died February 26; diaphragm heavily infested.

ARTIFICIAL DIGESTION TESTS IN EXPERIMENTS 1 TO 6.—Some of the meat used in each experiment was digested in an artificial gastric juice January 23. The trichinæ thus freed from their capsules were examined microscopically. They showed no visible evidence of injury, being active under heat stimulation and remaining tightly coiled at room temperature and thus behaving like normal trichinæ.

RESULTS OF EXPERIMENTS OF SERIES I.—These experiments indicate that trichinæ are seriously injured by sufficiently high dosages of X-rays. Although the trichinæ in all six experiments when freed from their cysts by artificial digestion showed no apparent evidence of having been affected by the X-ray treatment, the parasites in the meat that had been exposed to the heaviest dosage (experiments 1 and 2) failed to complete their development when fed to experimental animals. Instead of growing and developing in a normal manner, after the molt

that regularly occurs soon after the parasites reach the intestines, they underwent degenerative changes, and even in those cases in which the parasites developed to sexual maturity the reproductive processes were seriously disturbed. That the reproductive organs are especially susceptible to X-ray injury is clearly shown by the results of experiment 2. In this experiment the larvæ succeeded in attaining maturity, but the sex cells evidently failed to function.

It is also interesting to note that despite the fact that several rats in experiment 3 were not fed until 6 days after the meat had been exposed to X-rays, the animals developed an infection. Thus, in this experiment there was evident neither an immediate nor a delayed effect of the X-ray treatment upon the encysted parasites.

SERIES II

Three experiments are included in this series. The units of dosage used in this series have the same relative values as those in series I. Under date of February 5, 1917, the roentgenologist writes as follows:

> The package marked "A" (experiment 7) was given 600 units, the package marked "B" (experiment 8) 300 units, and the package marked "C" (experiment 9) 350 units. The 300 units given to package "B" were given with low density and extra long time. The packages marked "A" and "C" were given the 600 and 350 units, respectively, at high tension—that is, close to the tube and with short time.

EXPERIMENT 7.—Strength of dosage, 600 units. The meat was exposed 19 minutes.

Three rats were fed on February 8. Rat 1 died on March 1; diaphragm negative. Rat 2 died on March 2; diaphragm showed a slight infestation with trichinæ. Rat 3 died on March 6; diaphragm slightly infested with trichinæ.

EXPERIMENT 8.—Strength of dosage, 300 units. The meat was exposed 46 minutes.

Three rats were fed on February 8. Rats 1 and 2 died February 12; live trichinæ were found in the intestines. Rat 3 died on February 26; numerous larvæ were found in the fluid expressed from the diaphragm.

EXPERIMENT 9.—Strength of dosage, 350 units. The meat was exposed 10½ minutes.

Four rats were fed on February 8. Rat 1 died on February 21; numerous live trichinæ in intestines. Rat 2 died on February 28; diaphragm infested with encysted trichinæ. Rat 3 died on March 1; results as in No. 2. Rat 4 died on March 2; diaphragm heavily infested with trichinæ.

RESULTS OF EXPERIMENTS OF SERIES II.—The parasites in the meat used in experiment 7 were evidently affected by the exposure. That some of them, however, escaped the injurious influences of the exposure to X-rays may be concluded from the results of the feeding experiments which resulted in rather slight infections.

SERIES III

In this series, which includes 12 experiments, the dosages used had the same relative values as those of the preceding series. The time of exposure and distance from the focal spot in the X-ray treatment of the various samples of meat in this series of experiments were not given in concrete terms, but in experiments designated by the letter A the meat was placed at twice the distance from the focal spot and held four times as long as in experiments designated by the letter B.

Two rats were used in each feeding experiment. The rats were fed on May 14.

EXPERIMENT 10A.—Dosage, 674 units.

Both rats were killed on June 15; diaphragms heavily infested with trichinæ.

EXPERIMENT 10B.—Dosage, 674 units.

Rat 1 died on May 29; intestines negative; diaphragm negative. Rat 2 died on June 12; diaphragm negative.

EXPERIMENT 11A.—Dosage, 924 units.

Rat 1 died May 28; intestine negative; diaphragm negative. Rat 2 died on June 12; diaphragm negative.

EXPERIMENT 11B.—Dosage, 924 units.

Both rats killed on June 15; diaphragms heavily infested.

EXPERIMENT 12A.—Dosage, 1,363 units.

The rats were killed on June 15; diaphragms negative.

EXPERIMENT 12B.—Dosage, 1,363 units.

The rats died on June 17; diaphragms negative.

EXPERIMENT 13A.—Dosage, 2,162 units.

The rats were killed on June 15; diaphragms negative.

EXPERIMENT 13B.—Dosage, 2,162 units.

The rats were killed June 15; diaphragms negative.

EXPERIMENT 14A.—Dosage, 1,081 units.

Rat 1 dead June 5; one unencysted larva found in diaphragm. Rat 2 killed June 15; diaphragm heavily infested.

EXPERIMENT 14B.—Dosage, 1,081 units.

Rat 1 dead June 12; diaphragm heavily infested. Rat 2 killed June 15; results as in No. 1.

EXPERIMENT 15A.—Dosage, 3,094 units.

Rats killed June 15; diaphragms negative.

EXPERIMENT 15B.—Dosage, 3,094 units.

Rats killed June 15; diaphragms negative.

RESULTS OF EXPERIMENTS OF SERIES III.—In this series of experiments trichinous meat subjected to dosages up to 1,081 units proved to be infective, whereas in experiment 2 (series I) a dosage of 966 units impaired the vitality of the reproductive cells of the parasites. Whether this can be accounted for on the basis of variation of trichinæ to the effects of X-rays or whether other factors were involved can not be stated.

SERIES IV

Under date of June 28, the roentgenologist states that the meat used in this series of experiments was—

exposed to the direct action of the rays at a distance of very nearly 25 cm. from the focal spot of a Coolidge-type tube. The pressure across the tube terminals was 73 kilovolts, measured by standard sphere gap, and also by ratios. The current through the tube varied during the time of treatment, which extended over a period of about 3 hours. The lowest reading was 4.2 milliamperes, the highest 4.9. This high reading, however, was for only a short time after the tube was started. The current gradually dropped during 10 minutes to 4.3 milliamperes, and during the rest of the treatment fluctuated between 4.2 and 4.3 milliamperes.

The boxes were so placed that the rays from other tubes in the machine had very little influence on the contents. By calculation it shows as negligible.

Box A was given an exposure of 42 minutes; box B an exposure of 84 minutes; box C an exposure of 126 minutes; and box D an exposure of 168 minutes. Following the system of measurement used by Davey,[1] which has the merit of being a complete expression of X-ray quantity, these dosages would read:

Box A $180 \frac{\text{MAM}}{25^2}$ at 73 KV.

Box B $361 \frac{\text{MAM}}{25^2}$ at 73 KV.

Box C $542 \frac{\text{MAM}}{25^2}$ at 73 KV.

Box D $722 \frac{\text{MAM}}{25^2}$ at 73 KV.

The rats used in this series of experiments were fed on July 31 and August 3. Five rats were fed in each experiment.

EXPERIMENT 16 (BOX A), 42 MINUTES.—Rats 1 and 2 died August 4. A few trichinæ were found in the intestines. The parasites showed evidence of growth. The sex cells were strikingly disorganized. Other organs also showed evidence of injury. Rat 3 was killed on August 20; diaphragm moderately infested. Rat 4 died on August 29; diaphragm moderately infested. Rat 5 died on September 16; diaphragm moderately infested.

EXPERIMENT 17 (BOX B), 84 MINUTES.—Rat 1 died on August 6; intestines negative. Rat 2 died on August 17; intestines and diaphragm negative. Rat 3 died on August 18; results same as in rat 2. Rat 4 died on August 20; results same as in rat 2. Rat 5 was killed on September 10; diaphragm negative.

EXPERIMENT 18 (BOX C), 126 MINUTES.—Rats 1 and 2 were killed on August 20; diaphragms negative. Rats 3 and 4 were killed on September 10; diaphragms negative. Rat 5 was killed on September 10; diaphragm slightly infested.

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[1] Davey (OP. CIT., p. 586) states: "The voltage and distance are given directly and the product of the current and time is given, thus, '100 milliampere-minutes at 25 cm. distance at 50 kilovolts.' This is usually contracted to read $100 \frac{\text{MAM}}{25^2}$ at 50 kv. It will be noticed that distance is expressed in terms of its square. This is because the intensity of X-rays varies inversely as the square of the distance."

EXPERIMENT 19 (BOX D), 168 MINUTES.—Rat 1 was killed on August 7; intestine negative. Rat 2 was killed on August 20; intestine negative and diaphragm negative. Rat 3 died on September 5; diaphragm negative. Rats 4 and 5 were killed on September 10; diaphragms negative.

RESULTS OF EXPERIMENTS OF SERIES IV.—The X-ray dosages used in these experiments were clearly injurious to the trichinæ. The smallest dosage used (experiment 16) had some effect, though it did not destroy the reproductive functions of all the parasites. In the three other experiments in which considerably larger dosages were used only 1 infection occurred among the 15 experimental animals on which the infectiousness of the meat was tested, and that infection was slight.

SERIES V

This series included six experiments. The dosages used in these experiments were not indicated, except that two samples were given similar dosages and that the remaining samples received graded dosages. Furthermore, the samples were mixed so that it is not known which samples received the larger or the smaller dosages. The samples were treated on March 24. Experimental rats were fed in Washington on March 27.

EXPERIMENT 20.—Rat 1 died on April 5; no trichinæ were found in the intestines. Rat 2 was killed on April 9; intestines contained live trichinæ; female trichinæ contained many embryos; diaphragm negative. Rat 3 was killed April 16; intestines positive; diaphragm positive. Rat 4 was killed on April 24; diaphragm heavily infested.

EXPERIMENT 21.—Rat 1 was killed on April 9; intestines contained live trichinæ, normal in appearance; female trichinæ contained eggs and embryos. Rat 2 was killed on April 16; intestines contained many live trichinæ. Rat 3 died on April 24; diaphragm heavily infested.

EXPERIMENT 22.—Rat 1 was killed on April 8; intestines negative; diaphragm negative. Rat 2 was killed on April 16; diaphragm negative. Rat 3 died on April 17; diaphragm negative. Rat 4 died on April 24; diaphragm heavily infested.

EXPERIMENT 23.—Rat 1 was killed on April 9; live trichinæ were found in the intestines; sex cells were atrophied; no larvæ were found in the diaphragm. Rat 2 was killed on April 16; no trichinæ were found in the intestines; diaphragm negative. Rat 3 was killed on April 23; diaphragm negative. Rat 4 was killed on April 23; one encysted larva was found in the diaphragm.

EXPERIMENT 24.—Rat 1 was killed on April 2; intestines contained numerous live and apparently normal trichinæ. Rat 2 was killed on April 8; live trichinæ were found in the intestines; diaphragm negative. Rat 3 was killed on April 16; intestines contained trichinæ, apparently dead; diaphragm negative. Rat 4 was killed on April 24; diaphragm heavily infested. Rat 5 was killed on April 24; diaphragm negative.

EXPERIMENT 25.—Rat 1 was killed on April 9; intestines contained live trichinæ; sex cells of trichinæ atrophied; diaphragm negative. Rat 2 was killed on April 16; diaphragm negative. Rat 3 died on April 19; diaphragm negative. Rats 4 and 5 were killed on April 24; diaphragm negative.

RESULTS OF EXPERIMENTS OF SERIES V.—The results of these experiments are in harmony with the results of the experiments recorded in the preceding pages. Trichinæ that showed sex-cell injuries (experiments 23 and 25) failed to produce a new generation. That a few larvæ in experiment 23 escaped injury is evident from the results of the feeding experiment with rat 4. It is interesting to note, however, that despite the fact that the parasites showed evidence of injury they were still alive on the fourteenth day after artificial infection. This indicates that X-rays exert a selective action on the sex cells of trichinæ and that injuries to the sex cells do not necessarily affect the other vital functions of the parasites.

DISCUSSION

The results of the experiments described in the foregoing pages show that trichinæ may be seriously injured by X-ray radiation. It is interesting to note that in experiments 1 to 6 inclusive (series I), larvæ isolated from the treated meat by artificial digestion appeared to be unaffected. These larvæ were normal as to color and general appearance, as viewed through the microscope and as indicated by their reactions to heat stimulation. The examination was made three days after treatment. The larvæ from the meat treated in experiments 1 and 2 (series I) were incapable, however, of attaining full sexual maturity in the intestines of rats or mice. Those in experiment 1 and some of those in experiment 2 underwent granular degeneration, while others in the latter experiment succeeded in attaining maturity without being capable of functioning sexually. The fact that no spermatozoa were found in the receptaculum seminis of the female indicates that successful copulation had not taken place.

It is also of interest to observe that a considerable degree of variation in resistance to X-rays is exhibited by trichinæ, since certain dosages proved to be destructive in some cases and not in others. This is possibly due, however, to other factors. It may be noted in this connection that trichinæ exhibit considerable variation in their resistance to cold [1] and in their resistance to heat.[2]

Assuming that a reliable and practically possible method of destroying the vitality of the sex cells in trichinæ by means of X-ray treatment of infested meat can be perfected, which is quite uncertain, it is still questionable whether such a method would be acceptable as a prophylactic

[1] RANSOM, B. H. EFFECTS OF REFRIGERATION UPON THE LARVÆ OF TRICHINELLA SPIRALIS. *In* Jour. Agr. Research, v. 5, no. 18, p. 819–854. 1916. Literature cited, p. 853–854.

[2] ——— and SCHWARTZ, Benjamin. EFFECTS OF HEAT ON TRICHINÆ. *In* Jour. Agr. Research, v. 17, no. 5, p. 201–221. 1919. Literature cited, p. 220–221.

measure, inasmuch as trichinæ are not inoffensive as intestinal parasites apart from the damage done by their migrating larvæ. Rats, for example, commonly die from intestinal trichinosis prior to the migration of the larvæ, and human beings also often suffer seriously from the effects of the intestinal stage of the parasites during the first few days after infection before the migrating larvæ have been produced. Consequently, unless the X-ray treatment has the effect of diminishing the injurious action of the intestinal stage of trichinæ upon the host as well as of destroying their powers of reproduction, it can scarcely be considered a satisfactory prophylactic measure. It is of interest to note in this connection that Tyzzer and Honeij [1] found that encysted trichinæ that had been subjected to radium radiation failed to develop in mice. These investigators also determined that whereas radium radiation failed to destroy sexually mature trichinæ in live rats, trichinæ in rats which were radiated beginning with the second day after ingestion of trichinous meat showed retardation in development. Radiation of the larvæ in rats before they have begun to develop proved fatal to them.

SUMMARY

(1) Encysted trichinæ are injured by relatively heavy dosages of X-rays. So far as has been determined the injuries are not visible in the encysted or artificially decapsuled larvæ as structural or functional disturbances but become apparent only when the larvæ reach a suitable host animal in whose intestine they are normally capable of continuing their development.

(2) Trichinæ from meat that has been exposed to strong dosages of X-rays undergo rapid granular degeneration in the intestines of suitable hosts before they attain maturity.

(3) Encysted larvæ that have been exposed to lower but still injurious dosages of X-rays are able to continue development in the intestines of suitable hosts. Such larvæ, however, do not attain structural and functional sex maturity. The sex cells appear to be atrophied, and no evidence of successful copulation can be found. X-rays, therefore, appear to exert a more or less selective action on the gonads of trichinæ.

(4) Trichinæ appear to exhibit considerable variation in their susceptibility to X-rays, since certain dosages injured some parasites and failed to injure others. Whether the apparent variation in susceptibility of trichinæ to X-rays is an expression of an actual physiological variation or may be accounted for by other factors has not been determined.

(5) The experiments described in this paper do not warrant any definite conclusions as to the feasibility of using X-ray radiation as a practical means of destroying trichinæ in pork.

[1] TYZZER, E. E., and HONEIJ, James A. THE EFFECTS OF RADIATION ON THE DEVELOPMENT OF TRICHINELLA SPIRALIS WITH RESPECT TO ITS APPLICATION TO THE TREATMENT OF OTHER PARASITIC DISEASES. *In* Jour. Par., v. 3, no. 2, p. 43-56, 1 pl. 1916.

RELATION OF THE CALCIUM CONTENT OF SOME KANSAS SOILS TO THE SOIL REACTION AS DETERMINED BY THE ELECTROMETRIC TITRATION

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The importance of the soil reaction has led to the development of numerous methods for testing the neutrality, acidity, or alkalinity of the soil, and, if the soil is acid, for determining quantitatively the amount of agricultural lime necessary to add to the soil in order that it may have the reaction required for maximum crop production. No attempt will be made to review the literature on this subject, and only a few citations will be given.

Of the different tests designed simply to determine qualitatively the reaction of the soil, the litmus paper test is one of the oldest, best known, and probably most extensively used. This test has been subjected to much criticism, but this is probably due more to bad paper and faulty use than to intrinsic defects in the method. The official or Hopkins method (*15, p. 20*)[1] has been used for most of the acidity work done thus far on Kansas soils. It was found, however, that in some cases the indicated lime requirement appeared too low when studied in connection with the known cropping conditions of the soil. The well-known Veitch method (*14*) is probably the best quantitative measure of the lime requirements of the soil at the present time. There are several other methods proposed to determine the lime requirements of the soil, and each has its advocates. The strong advocate of any method is usually very free with his objections to some other method. All methods are limited in their application, and faults are often found with methods because the users extend the application further than the originators intended.

One difficulty in determining the soil reaction is to obtain the soil solution in the same concentration as it exists around the soil grains. Various methods have been proposed for securing this solution, but none have received general acceptance. Another factor is the facility with which the optimum reaction for best crop production is maintained in the soil. The concentration of the soil solution is in a state of continuous change. The film of water surrounding the soil grains in a soil of optimum water content tends to become saturated with the salts present in the soil. The

[1] Reference is made by number (italic) to "Literature cited," p. 867–868.

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addition of rain or irrigation water temporarily reduces the concentration. If some of the water is carried off in the drainage, it takes away a certain amount of the dissolved salts. At the present time calcium is removed from the soil more rapidly than any other base (*5, p. 23*). Lyon and Bizzell (*8*) found in lysimeter experiments that the equivalent of 485 pounds of calcium carbonate per annum leached from some soils. The continuous removal of calcium from the soil produces an unbalanced condition known as lime deficiency or acid soil. When calcium carbonate is added to the soil the balance is restored and the reaction is neutral or slightly alkaline.

The studies presented in this paper are not designed to settle any differences of opinion relative to the meaning of soil acidity nor to decide which is the best method of determining the lime requirement of the soil. They are presented as a contribution to the partial solution of a very complex as well as important problem. The electrometric titration has been used by a number of investigators (*6, 9, 10*). Because of its intrinsic value it was used in this study of the relation between the calcium content of some typical Kansas soil and the reaction.

MEANING OF SOIL ACIDITY

The following is usually taken as the meaning of acidity in soil: Total acidity means the total quantity of hydrogen ions which may be produced when the equilibrium is continually shifted by the introduction of hydroxyl ions. The quantity of hydrogen ions present at any one moment is regarded as the intensity of acidity. This definition would be inclusive and very convenient if it were not for the adsorptive power of colloids in soil. It will be shown that this intensity of acidity may be very small as related to the total acidity. Understood in this way, quantitatively, total acidity has the same meaning as potential acidity. Potential acidity may be due to undissolved substances, or to soluble compounds only partly hydrolyzed or dissociated. It appears also to be due to colloidal clay; but whatever it is due to, the conditions are such that as soon as more hydroxyl ions are introduced the equilibrium is shifted by the production of more hydrogen ions. The absolute neutral point obtains when the number of hydrogen ions and the number of hydroxyl ions are equal and each has a concentration of 10^{-7} per liter.

SOILS USED IN THIS STUDY

Twelve counties in Kansas have been surveyed and mapped by the Bureau of Soils, United States Department of Agriculture. Five of these counties were worked in cooperation with the Kansas Agricultural Experiment Station. These types have been sampled and analyzed by the Department of Chemistry, Kansas Agricultural Experiment Station (*1–4, 11*). Determinations have been made for nitrogen, phosphorus, potassium, carbon, carbon dioxid, and calcium. On the basis of these data

those soils which were thought most suitable were selected. In the description of these soils, the type names given by the Bureau of Soils are used. The soil numbers are those found in our soil series. The samples had been taken usually in three strata—namely, surface 0 to 7 inches, subsurface 7 to 20 inches, and subsoil 20 to 40 inches. For this work, surface soils mostly were selected, with a few accompanying subsoils. The soil number has a whole figure and a decimal. A surface soil is designated as 1083.1, subsurface as 1083.2, and a subsoil as 1083.3. Some of the samples were taken in only two strata.

The figures given for total calcium and carbon dioxid are taken from the publications to which reference has been made. In addition the authors have determined the calcium soluble in $N/1$ hydrochloric acid and in $N/5$ hydrochloric acid and the reaction as determined by the hydrogen electrode with accompanying titrations.

DETERMINATION OF ACID-SOLUBLE CALCIUM

Five gm. of soil were placed in 100 cc. $N/1$ hydrochloric acid and shaken for one hour on a shaking machine, then placed in a thermostat at 40° C. and digested for 23 hours with occasional shakings. The acid-soluble calcium was determined by the volumetric permanganate method. The treatment with $N/5$ hydrochloric acid was similar except that 10 gm. of soil and 200 cc. of the acid were used. The results on the calcium determinations are given in Table I.

Table I.—*Calcium and carbon dioxid in representative Kansas soils*

Soil No.	County.	Soil type.	Total Ca.	Ca. soluble in $N/1$ HCl.	Ca. soluble in $N/5$ HCl.	CO_2.
GROUP I, SOILS WHOSE INITIAL REACTION WAS MORE ALKALINE THAN IS INDICATED BY PH 8.3						
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
1043	Russell	Benton loam	4.89	4.01	4.19	4.37
1227	Greenwood	Crawford clay	3.25	3.30	3.18	.84
1297	Montgomery	Oswego silt loams	1.41	1.14	1.03	.20
1199	Jewell	Laurel very fine sandy loam	1.11	.60	.53	.10
1206	....do	Lincoln silty clay loam	1.01	.50	.69	.04
1186	Reno	Kirkland clay loam	.56	.48	.47	.10
1115	Finney	Richfield silt loam	.74	.32	.28	Trace.
1119	....do	Pratt loamy fine sand	.60	.10	.09	Do.
1169	Reno	....do	.40	.08	.05	.009
GROUP II, SOILS WHOSE INITIAL REACTION WAS BETWEEN PH 8.3 AND PH 7						
1219	Greenwood	Osage loam	0.88	0.80	0.80	0.11
1047	Brown	Silt loam (bottom)	.80	.66	.57	.04
1039	Russell	Summit silty clay loam	.83	.62	.54	.16
1132	Shawnee	Osage silty clay loam	.87	.59	.54	Trace
1268	Montgomery	Osage clay (alfalfa land)	.79	.52	.49	None.
1267	....do	Osage silty clay loam	.76	.49	.38	Do.
1121	Finney	Finney clay	.78	.31	.30	Trace.
1131	Shawnee	Osage very fine sandy loam	.79	.28	.36	Do.
1070	Reno	Pratt loam	.42	.20	.14	Do.
1157	....do	Arkansas clay loam	.70	.21	.19	.003
1120	Finney	Sandy loam	.44	.18	.16	Trace.
1072	Harper	Brown loam	.31	.18	.13	None.
1162	Reno	Pratt fine sandy loam	.49	.12	.12	.003
1160	....do	Arkansas fine sand	.55	.08	.07	.002

TABLE I.—*Calcium and carbon dioxid in representative Kansas soils*—Continued

GROUP III, SOILS WHOSE INITIAL REACTION WAS MORE ACID THAN IS INDICATED BY P_H 7

Soil No.	County.	Soil type.	Total Ca.	Ca. soluble in $N/1$ HCl.	Ca. soluble in $N/5$ HCl.	CO_2.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
1141	Shawnee....	Summit silty clay loam..................	0.54	0.42	0.41	0.016
1136	.....do.......	Oswego silt loam.........................	.55	.35	.31	.013
1285	Montgomery	Crawford loam...........................	.61	.34	.32	None.
1287	.....do.......	Summit silty clay loam..................	.55	.28	.25	Do.
1058	Doniphan...	Brown silt loam..........................	.47	.26	.21	Trace.
1284	Montgomery	Crawford loam...........................	.57	.25	.24	None.
1190	Jewell.......	Jewell silt loam..........................	.60	.24	.21	.01
1293	Montgomery	Bates stony loam.........................	.38	.24	.29	None.
1191	Jewell.......	Colby silt loam...........................	.63	.23	.21	.01
1135	Shawnee....	Crawford silty clay loam.................	.38	.23	.18	.01
1271	Montgomery	Bates loam...............................	.40	.21	.19	None.
1143	Shawnee....	Boone fine sandy loam..................	.37	.20	.18	Trace.
1256	Greenwood..	.....do....................................	.40	.18	.15	Do.
1262	Montgomery	Crawford loam...........................	.39	.32	....	None.
1233	Cherokee....	Oswego silty clay loam..................	.39	.17	.14	Trace.
1257	Greenwood..	Summit silty clay loam..................	.52	.17	.12	Do.
1265	Montgomery	Cherokee silt loam.......................	.46	.16	.13	None.
1273	.....do.......	Bates very fine sandy loam..............	.32	.16	.14	Do.
1275	.....do.......	Oswego silt loam.........................	.41	.15	.13	Do.
1232	Cherokee....	Bates silt loam...........................	.29	.14	.10	Trace.
1277	Montgomery	Bates shale loam.........................	.39	.14	.09	None.
1266	.....do.......	Bates very fine loam.....................	.34	.11	.09	Do.
1239	Cherokee....	Summit silt loam.........................	.51	.09	.08	Trace.
1243	.....do.......	Cherokee silt loam.......................	.30	.09	.07	Do.
1280	Montgomery	Bates loam...............................	.26	.09	.07	None.
1230	Cherokee....	Neosho silt loam.........................	.35	.08	.07	Do.
1279	Montgomery	Bates very fine sand.....................	.30	.06	.04	Do.
1148	Reno........	Dune sand................................	.36	.05	.04	.002
1244	Cherokee....	Bates fine sandy loam..................	.11	.05	.04	Trace.

DETERMINATION OF THE INITIAL REACTION AND THE ELECTROMETRIC TITRATION OF SOILS STUDIED

The apparatus used in these determinations was the same as that described in previous papers (*12, 13*). Ten gm. of soil were weighed into a 250-cc. bottle which was used as the electrode vessel, and 100 cc. of carbon-dioxid free water were added. The bottle was closed with a large rubber stopper through which were inserted the hydrogen electrode and the capillary tube connecting with the calomel cell. The hydrogen after bubbling through the soil suspension passed through a water trap, and the tip of the burette used in the titration was inserted through a hole in this stopper. In this way contamination from the carbon dioxid in the air was prevented. These precautions are necessary, since these determinations require a number of hours.

The distilled water used in this work was freed from carbon dioxid by aeration. While water so treated is not as neutral as conductivity water, the purity was sufficient for these determinations. The reaction of various samples of this water ranged from $P_H 6$ to $P_H 6.6$. One-tenth cc. of $N/10$ alkali would change the concentration from about P_H 6 to P_H 8. The error due to the water is therefore small. After the apparatus was adjusted, the hydrogen gas was bubbled through until equilibrium was obtained. The time required for this depended somewhat on the character of the soil. During the entire time the electrode vessel was shaken about 60 times per minute by a shaking device. As soon as the readings on the millivoltmeter remained constant within a few millivolts for 15

minutes, the soil suspension was considered to be at equilibrium. This point was noted and taken as the initial reaction of the soil. A solution of saturated calcium hydroxid is very near *N/24*. For the sake of facility in making calculations this was made *N/25*. Since the final end product of calcium hydroxid or calcium oxid added to the soil is calcium carbonate, this equivalent is used in making the calculations. One cc. of *N/25* calcium hydroxid is equivalent to 0.002 gm. of calcium carbonate. One acre of soil 7 inches deep is assumed to weigh 2,000,000 pounds. Since 10 gm. of soil were used in a determination, the ratio of the calcium carbonate equivalent of 1 cc. of the calcium hydroxid is 1:5,000. Accordingly, each cubic centimeter of calcium hydroxid used to titrate is equivalent to 400 pounds of calcium carbonate per acre.

When the voltmeter reading at the initial equilibrium point had been obtained, the calcium hydroxid was added from the burette in small portions at a time until the equilibrium was again obtained at voltmeter reading equivalent to P_H 7. The total number of cubic centimeters used in the titration were recorded, and again small portions of calcium hydroxid were added till equilibrium was established at voltmeter reading equivalent to P_H 8.3. This is approximately the titration end point for phenolphthalein. Again the calcium hydroxid was added until equilibrium was established at reading equivalent to P_H 10. The latter point was somewhat arbitrarily chosen.

A few grams of special "K" calcium carbonate were suspended in water, and after long shaking the reaction was found to be P_H 9.23. This is a little lower alkalinity than the value P_H 9.5 obtained by Sharp and Hoagland (*10*). The reading P_H 10 denotes a higher alkalinity than that found in a normal soil.

The electrometric measurements then gave these data: The initial reaction of the soil suspension stated as P_H; the total number of cubic centimeters of calcium hydroxid (*N/25*) required to change the reaction to P_H 7, P_H 8.3, and P_H 10, respectively. The results of these measurements are recorded in Table II.

TABLE II.—*Initial reaction of the soil and the number of cubic centimeters of N/25 calcium hydroxid used to change the reaction to the figures given* [a]

GROUP 1. SOILS WHOSE INITIAL REACTION WAS MORE ALKALINE THAN IS INDICATED BY P_H 8.3

Soil No.	County.	Soil type.	Initial P_H.	Cubic centimeters of $Ca(OH)_2$ required to titrate to— P_H 7.	P_H 8.3.	P_H 10.
1169	Reno	Pratt loamy fine sand	8.61			0.7
1227	Greenwood	Crawford clay	8.56			5.4
1043	Russell	Benton loam	8.52			3.7
1221	Greenwood	Oswego silt loam	8.51			9.3
1297	Montgomery	do	8.46			2.5
1199	Jewell	Laurel very fine sandy loam	8.44			12.3
1119	Finney	Dune sand	8.44			4.4
1206	Jewell	Lincoln silty clay loam	8.40			4.0
1186	Reno	Kirkland clay loam	8.37			7.1

[a] Figures arranged according to increasing hydrogen-ion concentrations.

TABLE II.—*Initial reaction of the soil and the number of cubic centimeters of N/25 calcium hydroxid used to change the reaction to the figures given*—Continued

GROUP II, SOILS WHOSE REACTION WAS BETWEEN P_H 8.3 AND P_H 7

Soil No.	County.	Soil type.	Initial P_H.	Cubic centimeters of $Ca(OH)_2$ required to titrate to— P_H 7.	P_H 8.3.	P_H 10.
1039	Russell	Summit silty clay loam	8.03	....	1.5	13.2
1219	Greenwood	Osage loam	7.81	....	3.0	10.1
1120	Finney	Sandy loam	7.50	....	2.0	6.8
1047	Brown	Silt loam (bottom)	7.49	....	.5	1.0
1132	Shawnee	Osage silty clay loam	7.45	....	2.7	8.7
1268	Montgomery	Osage clay (alfalfa land)	7.40	....	2.9	8.4
1267	do	Osage silt clay loam	7.36	....	3.0	19.1
1072	Harper	Brown loam	7.28	....	3.5	8.3
1160	Reno	Arkansas fine sand	7.26	....	1.4	3.5
1157	do	Arkansas clay loam	7.26	....	3.8	10.4
1070	do	Pratt loam	7.22	....	5.3	13.0
1131	Shawnee	Osage very fine sandy loam	7.19	....	2.0	4.6
1121	Finney	Finney clay	7.17	....	1.7	5.1
1162	Reno	Pratt fine sandy loam	7.05	....	6.9	16.1

GROUP III, SOILS WHOSE INITIAL REACTION WAS MORE ACID THAN IS INDICATED BY P_H 7

Soil No.	County.	Soil type.	Initial P_H.	P_H 7.	P_H 8.3.	P_H 10.
1287	Montgomery	Summit silty clay loam	6.77	2.5	5.3	11.4
1143	Shawnee	Boone fine sandy loam	6.76	.8	9.0	19.7
1191	Jewell	Colby silt loam	6.72	1.2	3.7	13.0
1190	do	Jewell silt loam	6.71	.8	3.6	7.9
1285	Montgomery	Crawford loam	6.65	1.0	4.2	12.5
1243	Cherokee	Cherokee silt loam	6.55	1.3	6.2	14.1
1230	do	Neosho silt loam	6.53	1.3	4.6	8.9
1058	Doniphan	Brown silt loam	6.53	1.3	5.1	10.2
1148	Reno	Dune sand	6.46	.6	2.3	4.2
1266	Montgomery	Bates very fine sandy loam	6.36	2.6	5.2	11.5
1271	do	Bates loam	6.29	2.4	6.5	20.2
1284	do	Crawford loam	6.25	.5	1.8	4.7
1141	Shawnee	Summit silty clay loom	6.15	6.7	17.5	31.4
1135	do	Crawford silty clay loam	6.01	8.4	20.0	35.2
1232	Cherokee	Bates silt loam	5.92	4.3	9.4	16.1
1136	Shawnee	Oswego silt loam	5.84	7.0	17.9	30.6
1256	Greenwood	Boone fine sandy loam	5.72	9.1	15.3	29.6
1279	Montgomery	Bates very fine sand	5.70	2.6	6.0	11.7
1265	do	Cherokee silt loam	5.56	6.7	10.3	23.2
1277	do	Bates shale loam	5.56	6.8	15.0	29.3
1280	do	Bates loam	5.54	3.1	6.0	13.5
1273	do	Bates very fine sandy loam	5.53	6.1	11.0	24.1
1257	Greenwood	Summit silty clay loam	5.49	9.2	22.0	35.3
1293	Montgomery	Bates stony loam	5.49	3.1	4.5	9.1
1275	do	Oswego silt loam	5.35	8.2	10.5	18.8
1233	Cherokee	Oswego silty clay loam	4.99	8.2	14.3	25.2
1244	do	Bates fine sandy loam	4.99	7.1	12.4	24.0
1239	do	Summit silt loam	4.68	9.8	19.3	31.0

CLASSIFICATION ON THE BASIS OF REACTION

When the data obtained, both in the calcium determinations and the electrometric measurements, were brought together it was found convenient to classify the soils into three groups. In group I were placed those soils whose initial reaction was more alkaline than is indicated by P_H 8.3. In group II were placed those soils whose initial reaction were less alkaline than is indicated by P_H 8.3 but more alkaline than is indicated by P_H 7. In group III were placed those soils whose initial reaction was more acid than is indicated by P_H 7. In arranging the soils within these groups the figures in Table I are given according to decreasing amounts of calcium soluble in *N/1* hydrochloric acid. In Table II the soils are arranged according to decreasing alkalinity, or increasing acidity, as expressed by the P_H values.

CALCIUM CONTENT OF SOILS STUDIED

The soils of highest calcium content are found in group I. The four soils in group I which have as low calcium content as several of the soils in group II, or lower, are from the drier portion of the State. The soils in group III have an average lower calcium content than the soils in groups I and II. In general, the soils of a high calcium content have a more alkaline reaction than soils of low calcium content; yet because of the exceptions, the calcium content alone can not serve as the basis of classification as acid or alkaline. Most of the soils in group I are from the section of the State where acid soils are not usually found, whereas most of the soils from group III are from the section of the State where acid soils are more common. Sandstone-derived soils from the drier portions of the State may have a comparatively small amount of calcium and yet have an alkaline reaction.

In soils of high calcium content a larger percentage of the amount present is soluble in acid than in soils of low calcium content. As the percentage of total calcium decreases, it is relatively less soluble. This is true in comparing the groups and in comparing soils within groups. In group I the proportion of acid-soluble calcium is greater than in group II, and in group II it is greater than in group III.

The differences in the amounts of calcium in forms soluble in *N/1* hydrochloric acid and in *N/5* hydrochloric acid are small. For practical purposes they are of equal value.

The pronounced differences between the amounts of calcium soluble in hydrochloric acid and the total, especially in soils of low calcium content, raises the question of the relative importance of determining the total calcium in a soil or determining the amount soluble in cold dilute hydrochloric acid. These figures would indicate that the results obtained by the acid digestion are more valuable. In soils of low calcium content, it is present mostly in insoluble forms. While weathering gradually converts this calcium into forms that are soluble, the amount of available calcium obtained is insufficient for the needs of the soil. Such soils are deficient in "agricultural lime."

The figures for percentage of carbon dioxid show that all the soils in group I have some carbonates, that only 6 of the 14 soils in group II have carbonates in larger amounts than traces, and that only 3 of the soils in group III have carbonates in larger amounts than traces and in these the amounts are very small.

RESULTS OF ELECTROMETRIC MEASUREMENTS

The results on the electrometric measurements found in Table II are arranged according to decreasing alkalinity values or, which means the same thing, increasing acidity values. The figures expressing cubic centimeters of calcium hydroxid under the different P_H values in each case

mean the total calcium hydroxid used to bring the reaction to that point. In interpreting the results of these electrometric measurements the following factors must be considered: (1) Kind of soil with reference to the amount of sand, clay, and organic matter; (2) influence of climatic conditions; (3) amount of calcium present, particularly in the carbonate form. The amount of sand, silt, clay, or organic matter present in a soil may have a greater influence on the initial reaction than the amount of calcium present. Pratt loamy fine sand from Reno County has the lowest calcium content of the soils placed in group I, Table I, but it has the highest alkalinity as shown in Table II. Benton loam No. 1043 and Crawford clay No. 1227 are both high in calcium and both have a high initial alkaline reaction. The clay soils and the silty clay soils as a rule require more calcium hydroxid to change to a certain hydrogen-ion concentration than the sandy soils.

Soils placed in group III, Table II, are distinctly acid in reaction. As the initial acidity increases, the amounts of calcium hydroxid needed to change the reaction to neutral (indicated by P_H 7) also increases, but not uniformly. This is due to factors mentioned in the preceding paragraph. The influence of clay is shown by the figures in Table III.

Subsoils as a rule contain a larger amount of calcium than the surface soils, particularly calcium in the carbonate form. These same subsoils usually contain a larger amount of clay but a smaller amount of organic matter. The calcium was determined in a number of the subsoils corresponding to the surface soils mentioned in Tables I and II. The electrometric measurements were also made. The results are found in Table III. The figures for the surface soils are repeated from Tables I and II for the sake of comparison. The results in Table III are arranged within the groups with reference to the decreasing amounts of calcium in the surface soils. The results show that, with few exceptions, the subsoils have a higher calcium content than the surface soil and that in the majority of cases the subsoil requires a larger amount of calcium hydroxid to change it to the same reaction as the surface soil.

The soils in which the calcium content is less in the subsoil than in the surface soil are: 1297, Oswego silt loam; 1271, Bates loam; 1273, Bates very fine sandy loam; and 1277, Bates shale loam. In the first one of these soils the titration figure is larger for the subsoil than for the surface soil. This would be expected from the larger clay content and the smaller amount of calcium. The last two have sandy subsoils; and while no mechanical analyses were made, observations recorded at the time of taking the samples show that the subsoils have less clay than the surface soils. Both these soils were acid, and the subsoil is more acid than the surface soil. Yet the lesser amount of clay in the subsoil was of more influence in determining the amount of calcium hydroxid needed to bring to neutral reaction than the initial acidity.

TABLE III.—*Calcium content and electrometric measurements on subsoils in comparison with surface soils*

Soil No.	County.	Soil type.	Calcium soluble in N/1 HCl, calculated to equivalent of $CaCO_3$ per acre 7 inches deep.	Initial P_H.	Cubic centimeters of N/25 $Ca(OH)_2$ required to titrate to—		
					P_H 7.	P_H 8.3.	P_H 10.
GROUP I, SOILS WHOSE INITIAL REACTION WAS MORE ALKALINE THAN IS INDICATED BY P_H 8.3							
			Pounds.				
1043.1	Russell	Benton loam	200,500	8.52	....	....	3.7
1043.3			643,000	8.56	....	....	5.0
1227.1	Greenwood	Crawford clay	165,000	8.56	....	....	5.4
1227.3			206,000	8.75	....	....	8.0
1297.1	Montgomery	Oswego silt loam	57,000	8.46	....	....	2.5
1297.3			42,000	9.03	....	....	7.2
1199.1	Jewell	Laurel very fine sandy loam	30,000	8.44	....	....	5.3
1199.3			40,000	9.03	....	....	2.0
1206.1	....do	Lincoln silty clay loam	25,000	8.40	....	....	4.8
1206.3			45,500	8.40	....	....	7.6
1169.1	Finney	Pratt loamy fine sand	4,000	8.61	....	....	.7
1169.2			5,000	8.61	....	....	.5
GROUP II, SOILS WHOSE INITIAL REACTION WAS BETWEEN P_H 8.3 AND P_H 7							
1085.1	Riley	Laurel silt loam	71,500	8.16	....	0.7	7.9
1085.3			73,000	8.16	....	.7	7.9
1047.1	Brown	Silt loam, bottom	33,000	7.49	....	.5	1.0
1047.3			53,500	8.68	....	....	15.6
1039.1	Russell	Summit silty clay loam	31,000	8.03	....	1.5	13.2
1039.3			78,500	8.28	....	....	17.7
1121.1	Finney	Finney clay	15,000	7.17	....	1.7	5.1
1121.3			23,000	8.44	....	....	1.4
1070.1	Reno	Pratt loam	10,000	7.22	1.1	12.6	13.0
1070.3			14,000	6.67	....	3.8	26.7
1157.1	....do	Arkansas clay loam	10,500	7.26	....	3.8	10.4
1157.3			76,500	8.39	....	....	9.0
1120.1	Finney	Sandy loam	9,000	7.50	....	2.0	....
1120.3			105,500	8.92	....	....	....
1072.1	Harper	Brown loam	9,000	7.28	....	3.5	....
1072.3			26,500	8.44	....	....	....
1162.1	Reno	Pratt fine sandy loam	6,000	7.05	....	6.9	....
1162.3			8,500	6.95	....	6.2	....
GROUP III, SOILS WHOSE INITIAL REACTION WAS MORE ACID THAN IS INDICATED BY P_H 7							
1115.1	Finney	Richfield silt loam	16,000	6.57	0.8	10.4	....
1115.3			177,000	8.34	....	....	....
1287.1	Montgomery	Summit silty clay loam	14,000	6.77	2.5	5.3	....
1287.3			17,000	6.13	1.7	3.8	....
1058.1	Doniphan	Brown silt loam	13,000	6.53	1.3	5.1	....
1058.3			14,000	6.32	4.0	15.3	....
1190.1	Jewell	Jewell silt loam	12,000	6.71	.8	3.6	....
1190.3			67,000	8.30	....	....	....
1191.1	....do	Colby silt loam	11,500	6.72	1.2	3.7	....
1191.3			38,500	8.44	....	....	....
1135.1	Shawnee	Crawford silty clay loam	11,500	6.01	8.4	20.0	....
1135.3			38,000	6.80	....	....	....
1233.1	Cherokee	Oswego silty clay loam	8,500	4.99	8.2	14.3	....
1233.3			11,500	4.42	10.3	21.6	....
1257.1	Greenwood	Summit silty clay loam	8,500	5.49	9.2	22.0	....
1257.3			23,000	7.90	....	2.1	....
1265.1	Montgomery	Cherokee silt loam	8,000	5.56	6.7	10.3	....
1265.3			12,500	5.20	6.4	11.9	....
1275.1	....do	Oswego silt loam	7,500	5.32	8.2	10.5	....
1275.3			12,000	5.32	7.6	14.8	....
1271.1	....do	Bates loam	10,500	6.29	2.4	6.5	....
1271.2			7,000	5.46	3.1	6.5	....
1273.1	....do	Bates very fine sandy loam	8,000	5.53	6.1	11.0	....
1273.2			6,000	5.44	4.9	9.6	....
1232.1	Cherokee	Bates silt loam	7,000	5.92	4.3	9.4	....
1232.3			8,000	5.21	4.2	10.1	....
1277.1	Montgomery	Bates shale loam	7,000	5.56	6.8	15.1	....
1277.2			4,000	5.15	7.7	13.4	....
1243.1	Cherokee	Cherokee silt loam	4,500	6.55	1.3	6.2	....
1243.3			9,500	5.66	4.6	8.7	....
1230.1	....do	Neosho silt loam	4,000	6.53	1.3	4.6	....
1230.3			7,500	5.66	5.7	11.1	....
1244.1	....do	Bates fine sandy loam	2,500	4.99	7.1	12.4	....
1244.2			3,500	4.94	8.1	15.2	....

Of the 34 soils represented in Table III, 13 required less calcium hydroxid for the titration of the subsoil than for the surface soil. Eight of these 13 soils have over three times as much calcium in the subsoil as in the surface soil. From the figures presented in Tables I and II, it is shown that when a soil has large amounts of calcium, especially in the carbonate form, the amount of calcium hydroxid used to bring to a certain reaction was less than when the calcium content was smaller. That is shown by comparisons of the groups. A large amount of calcium has a greater influence than a larger amount of clay.

The result on soil No. 1273 can be explained by the lesser clay content of the subsoil, as was pointed out in a preceding paragraph.

The following four soils have only slightly more calcium in the subsoil, and yet they require less calcium hydroxid for the subsoil than for the surface soil:

1199.3, Laurel very fine sandy loam.
1162.3, Pratt fine sandy loam.
1121.3, Finney clay.
1287.3, Summit silty clay loam.

The results on the first two may be explained by the lesser clay content of the subsoil. Finney clay 1121.3 is an abnormal soil. The sample was taken from the edge of a buffalo wallow. The probability is that the surface soil had more colloidal clay than the subsoil. Sample 1687 must be an exception; no explanation is apparant.

The foregoing presentation shows that most subsoils have a greater calcium content than the surface soil and also that the subsoils require a larger amount of calcium hydroxid to bring to the same reaction as the surface soil. This must be due to the absorptive power of the colloidal clay. It can not be due to a larger acid content or to a deficiency of basic elements. The larger content of calcium should neutralize the acidity, and since the calcium content is larger in the subsoil than in the surface soil in can not very well be said than the subsoil is more deficient in lime.

The initial reaction of a soil is not necessarily an indication of the amount of calcium hydroxid required to titrate to a given hydroxyl-ion concentration. In Table II the results are arranged according to the decreasing hydroxyl-ion concentration of the soil before titration. If these figures are studied in comparison with the figures in Table I it is found that the amounts used to titrate do not correspond to the initial reaction nor to the content of calcium except in the following general way. The soils placed in group I have a larger calcium content than the soils in group II, and those in group II have a larger calcium content than those in group III. The quantities of calcium hydroxid used in titration are greater for soils in group III than for soils in group II, and greater for those in group II than for those in group I. But for individual soils this comparison does not hold.

The total acidity in the soil was mentioned in a preceding paragraph as the total quantity of hydrogen ions which may be produced when the equilibrium is continually shifted by the introduction of hydroxyl ions. On such a basis it is possible to calculate the amount of lime required to satisfy this acidity as measured by the electrometric titration. It was also shown in a preceding paragraph that 1 cc. of N/25 calcium hydroxid used in titrating 10 gm. of soil is equivalent to 400 pounds of calcium carbonate per acre. Table IV has been prepared by using this factor and the titration figures from Table II. In the last column of Table IV are given the figures of the lime requirement of these soils as determined by the Hopkins method. It is at once seen that there is no close agreement in the figures obtained by the two methods. This does not necessarily argue for the greater practical value of the figures obtained by the electrometric method nor against the Hopkins method. Similar disagreements can be found if other well-known acidity methods are compared. The figures presented in Table III make it appear that some of the calcium hydroxid is taken up by colloidal clay. Just how much this amounts to is not known, nor the manner. This forms part of an investigation now going on at this laboratory.

Methods do not show any agreement as to the amount of calcium carbonate that should be added to an acid soil. Hopkins (7) states that 10 tons of limestone per acre on some soils is not too large a quantity. The figures in Table IV show that the amounts of lime required to change from a more acid reaction than denoted by P_H 7 to neutral, or P_H 7, is not in general larger than the figures obtained by the Hopkins method, though there is no agreement between individual samples. The amounts required to change from the initial reaction to that denoted by P_H 8.3 are not far from the amounts recommended for use on acid soils, and the amounts required to bring the reaction to P_H 10 are in all cases less than 10 tons per acre.

Table IV.—*Electrometric measurements in equivalents of $CaCO_3$ per acre in 0 to 7 inches of the surface soil in comparison with amount of $CaCO_3$ required by the Hopkins method*[a]

GROUP 1, SOILS WHOSE ALKALINITY WAS ABOVE P_H 8.3

Soil No.	County.	Soil type.	Initial P_H.	Pounds per acre of $CaCO_3$ equivalent to titration of—			Pounds per acre of $CaCO_3$ required by the Hopkins method.
				P_H 7.	P_H 3.	P_H 10.	
1169	Reno	Pratt loamy fine sand	8.61	....	....	280	....
1227	Greenwood	Crawford clay	8.56	....	....	2,160	Alkali.
1043	Russell	Benton loam	8.52	....	....	1,480	....
1297	Montgomery	Oswego silt loam	8.46	....	....	1,000	Alkali.
1199	Jewell	Laurel very fine sandy loam	8.44	....	....	4,920	....
1119	Finney	Dune sand	8.44	....	....	1,760	....
1206	Jewell	Lincoln silty clay loam	8.40	....	....	1,600	....
1186	Reno	Kirkland clay	8.37	....	....	2,840	....

[a] It is assumed that 1 cc. of $N/25$ $Ca(OH)_2$ is equivalent to 400 pounds $CaCO_3$ per acre.

TABLE IV.—*Electrometric measurements in equivalents of $CaCO_3$ per acre in 0 to 7 inches of the surface soil in comparison with amount of $CaCO_3$ required by the Hopkins method*—Continued

SOILS WHOSE REACTION WAS BETWEEN P_H 7 AND P_H 8.3

Soil No.	County.	Soil type.	Initial P_H.	Pounds per acre of $CaCO_3$ equivalent to titration of—			Pounds per acre of $CaCO_3$ required by the Hopkins method.
				P_H 7.	P_H 3.	P_H 10.	
1085	Riley	Laurel silt loam	8.16	....	280	3,160	....
1039	Russell	Summit silty clay loam	8.03	....	600	5,280	....
1219	Greenwood	Osage loam	7.81	....	1,200	4,040	....
1120	Finney	Sandy loam	7.50	....	800	2,720	....
1047	Brown	Silty loam bottom	7.49	....	200	400	....
1132	Shawnee	Osage silty clay loam	7.45	....	1,080	3,480	....
1268	Montgomery	Osage clay (alfalfa land)	7.40	....	1,160	3,360	340
1267	....do	Osage silty clay loam	7.36	....	1,200	7,640	340
1072	Harper	Brown loam	7.28	....	1,400	3,320	....
1160	Reno	Arkansas fine sand	7.26	....	560	1,400	....
1157	....do	Arkansas clay loam	7.26	....	1,520	4,160	....
1070	....do	Pratt loam	7.22	....	2,120	5,200	....
1131	Shawnee	Osage very fine sandy loam	7.19	....	800	1,840	....
1121	Finney	Finney clay	7.17	....	680	2,040	....
1162	Reno	Pratt fine sandy loam	7.05	....	2,760	6,440	....

SOILS WHOSE ALKALINITY WAS BELOW P_H 7

Soil No.	County.	Soil type.	Initial P_H.	P_H 7.	P_H 3.	P_H 10.	Hopkins method.
1287	Montgomery	Summit silty clay loam	6.77	1,000	2,120	4,560	340
1143	Shawnee	Boone fine sandy loam	6.76	320	3,600	7,880	....
1191	Jewell	Colby silt loam	6.72	480	1,480	5,200	....
1190	....do	Jewell silt loam	6.71	320	1,440	3,160	....
1243	Cherokee	Cherokee silt loam	6.55	520	2,480	5,640	580
1230	....do	Neosho silt loam	6.53	520	1,840	3,560	200
1058	Doniphan	Brown silt loam	6.53	520	2,040	4,080	....
1148	Reno	Dune sand	6.46	240	920	1,680	....
1266	Montgomery	Bates very fine sandy loam	6.36	1,040	2,080	4,600	680
1271	....do	Bates loam	6.29	960	2,600	8,080	340
1284	....do	Crawford loam	6.25	200	720	1,880	340
1141	Shawnee	Summit silty clay loam	6.15	2,680	7,000	12,560	....
1135	....do	Crawford silty clay loam	6.01	3,360	8,000	14,080	....
1232	Cherokee	Bates silt loam	5.92	1,720	3,760	6,440	620
1136	Shawnee	Oswego silt loam	5.84	2,920	7,160	12,240	....
1224	Greenwood	Summit stony loam	5.82	2,400	5,240	9,200	Alkali.
1256	....do	Boone fine sandy loam	5.72	3,640	6,120	11,840	440
1279	Montgomery	Bates very fine sand	5.70	1,040	2,400	4,680	1,700
1265	....do	Cherokee silt loam	5.56	2,680	4,120	9,280	1,700
1277	....do	Bates shale loam	5.56	2,720	6,040	11,720	680
1280	....do	Bates loam	5.54	1,240	2,400	5,400	2,380
1273	....do	Bates very fine sandy loam	5.53	2,440	4,400	9,040	1,700
1257	Greenwood	Summit silty clay loam	5.49	3,680	8,800	14,120	480
1293	Montgomery	Bates stony loam	5.49	1,240	1,800	3,640	3,740
1275	....do	Oswego silt loam	5.35	3,280	4,200	7,520	2,380
1233	Cherokee	Oswego silty clay loam	4.99	3,280	5,720	10,080	270
1244	....do	Bates fine sandy loam	4.99	2,840	4,960	9,600	1,020
1239	....do	Summit silt loam	4.68	3,920	7,720	12,400	490

SUMMARY

(1) A number of soils from different parts of Kansas were analyzed for total calcium, calcium in forms soluble in $N/5$ hydrochloric acid, and in $N/1$ hydrochloric acid. The amount of carbon dioxid in these soils was also determined.

(2) Ten-gm. samples of these soils were placed in 100 cc. neutral distilled water, and the initial reaction was determined by means of the

hydrogen electrode. *N*/5 calcium hydroxid was added to change the reaction to a higher alkalinity. The points determined were the number of cubic centimeters of *N*/25 calcium hydroxid needed to bring the reaction (if lower) to P_H 7, P_H 8.3, and P_H 10.

(3) In soils of a high calcium content, a larger percentage of the calcium is in forms soluble in these dilute hydrochloric acid solutions than in soils of a low calcium content.

(4) As a rule, soils of a high calcium content have a higher initial hydroxyl-ion concentration than soils of low calcium content.

(5) The amount of *N*/25 calcium hydroxid required to change a soil from a lower to a higher hydroxyl-ion concentration depends more upon the amount of colloidal clay present than upon the calcium content.

(6) Subsoils, as a rule, have a higher calcium content than surface soils. It required more calcium hydroxid to change these subsoils from a lower to a higher hydroxyl-ion concentration than it did for the corresponding surface soils. This was true for most of the soils. The exceptions were due either to a very high calcium content in the subsoil as compared with the surface soil, or to a larger amount of sand in the subsoil, or to some unusual condition of the soil and subsoil.

(7) The amount of *N*/25 calcium hydroxid required to change the acid soils to a reaction represented by P_H 7, calculated in equivalent pounds of calcium corbonate per acre, compares favorably with some other current methods of determining the lime requirements of the soil.

(8) In some soils the amount of calcium hydroxid, calculated in equivalents of pounds of calcium carbonate per acre, required to change to a concentration represented by P_H 8.3 is as great as the equivalent amount of acid-soluble calcium present in the soil, or greater.

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GREEN FEED VERSUS ANTISEPTICS AS A PREVENTIVE OF INTESTINAL DISORDERS OF GROWING CHICKS

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The problem of raising chicks in confinement has engaged the attention of many nutrition investigators for years. The difficulties encountered have been attributed to various causes, such as lack of vitamines in the feed, lack of exercise, and intestinal putrefaction. Whatever the causes may be it is recognized that they have proved a serious handicap in making use of the chick in nutrition work. The critical time in the life of a chick is between the ages of 8 and 12 weeks. During this period by far the greater mortality occurs when they are kept in confinement, and this is a most serious objection to their use in nutrition investigation. Drummond [1] has made some study of the growth of chicks in confinement and concludes that it is impossible to grow them successfully even when the feed is known to be suitable for growth. Osborne and Mendel [2] also report difficulty in raising chicks in confinement and have found the use of paper pulp to aid somewhat in lessening mortality. Hart and his associates [3] report difficulty in growing young chicks in confinement but have found no trouble in using birds weighing 3 or 4 pounds. The authors [4] have reported some success in raising chicks in confinement, but at that time it was thought the fair growth obtained was due to the green feed given in the ration. However, better results have since been secured without any green feed in the ration. The green feed was thougth to give the necessary succulence and add the vitamines needed for growth; but later experience does not indicate this to be true. The question now arises in the minds of the writers as to whether greens are necessary in the ration of a young growing chick. In three years' work with growing chicks in confinement there was no extra gain in weight or decreased mortality where sprouted oats were fed, over that of the control pens; in fact the chicks receiving greens were less vigorous than those in the other lots. It may be noted in this connection at Purdue University that in eight years of feeding 2-year-old steers in preparing them for the market there was no advantage gained, so far as the

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average daily gain or selling price was concerned, by those steers receiving varying amounts of silage over those receiving only dry feed, except that the gains were made in the former case at a slightly reduced cost as compared with the latter, due largely to the fact that silage is cheaper than clover hay.

OBJECT OF THIS INVESTIGATION

Since sprouted oats seemed to be inefficient in preventing chick mortality, an attempt was made during the year 1919 to find some means of checking intestinal putrefaction, which postmortem examinations have shown to be the principal cause of mortality. Accordingly it was decided to try a series of different compounds which might be expected to have an antiseptic effect or might serve to prevent impaction by reason of their bulk.

THE EXPERIMENT

The stock used was 160 White Leghorn day-old chicks, which were divided into 10 lots of 16 chicks each. Every precaution was exercised to distribute the chicks so that they would be uniform in all lots. During the first four days the chicks in all lots were given water and granulated corn and had access to sand. Thereafter they were given their respective rations. At this time each bird was leg-banded and its weight was recorded. They were weighed individually at the end of each 14 days thereafter until the close of the experiment, at the end of 14 weeks. The weight of feed consumed by each lot was recorded each time the chicks were weighed.

The basal ration used was one which had proved most satisfactory during the past two years of feeding trials, including two different experiments—one with White Leghorns and the other with White Plymouth Rock chicks. All lots received the basal ration consisting of 50 parts cracked corn, 35 parts corn meal, 15 parts corn bran, 3 parts ash, 8.86 parts meat scrap, and 10.9 parts soybean meal (all parts by weight), and were provided with 1 inch of sand on the floor. In addition to this, some other factor was included in all lots, except in lot No. 1 which was the control pen. Lot No. 2 was provided with oat straw litter to note what effect the increased exercise or consumption of straw would have. Lot No. 3 was fed like No. 2, except that it received green feed in the form of tops of sprouted oats. The care of this lot represented the management usually given brooder chicks, since it provided a well-balanced ration and in addition supplied scratching litter and green feed. The exception to the usual brooder practice was that the birds were kept in confinement. Lots 3, 11, 13, and 14 are the lots reported in the tables as receiving green feed.

The idea has been advanced by some that the benefit of the scratching litter was derived not from the exercise it promoted but from the large quantities of the litter that were consumed by the birds, providing an

abundance of fiber which is considered so beneficial in the digestive tract. In view of this possibility, lots 4 and 5 were fed straw pulp. The only difference in the treatment of these two lots was that No. 4 received but one-half as much of the straw pulp as did No. 5. This pulp was prepared by taking strawboard (made of straw) and reducing it to a pulp with water. This pulp, after most of the water was expelled, was mixed with the dry mash. This was bulky, especially the mixture fed lot 5. The actual dry-weight consumption of paper was approximately 2½ and 5 per cent of the ration for lots 4 and 5, respectively. This pulp was palatable when mixed in the feed, and the chicks would eat it fairly well.

Lot 6 received the basal ration with hydrochloric acid added to the drinking water at the rate of 1 part 36 per cent hydrochloric acid (HCl) to 500 parts of drinking water. This is sometimes recommended as a substitute for buttermilk for use as a preventive or corrective of blackhead in turkeys and of bacillary white diarrhea and coccidosis in chickens.

Tobacco dust, a by-product of tobacco manufacturing and a valuable remedy against intestinal parasites, was given to lot No. 7 at the rate of 2 parts added to the basal ration. In like maner lot No. 8 received 2 parts of sulphur, and No. 9 received 6 parts of lactose. Lot No. 10 received the basal ration with copper sulphate added to the drinking water at the rate of 1 part copper sulphate crystals ($CuSO_4$) to 1,400 parts of water.

The mortality records and weights for the different lots are given in Table I.

TABLE I.—*Weight and mortality of chicks*

Lot No.	Ration.	Age, 8 weeks.		Age, 14 weeks.	
		Weight.	Mortality.	Weight.	Mortality.
		Gm.		*Gm.*	
1	Basal only	257	0	644	6
2	Basal+straw	252	3	475	8
3	Basal+straw and greens	257	3	524	8
4	Basal+2½ per cent straw pulp (No. 1)	247	3	630	6
5	Basal+5 per cent straw pulp (No. 2)	252	8	638	8
6	Basal+HCl	305	4	639	5
7	Basal+tobacco	223	4	535	6
8	Basal+sulphur	305	5	605	7
9	Basal+lactose	295	4	617	7
10	Basal+$CuSO_4$	306	2	653	2
11	Basal+greens [a]	243	1	384	11
12	Basal+greens [b]	186	3	360	11
13	Basal+no greens [c]	225	5	486	10
14	Basal+greens [d]	205	3	458	8

[a] Experiment No. I (1918), White Leghorns, fed same ration as Lot No. 3.
[b] Experiment No. II (1919), White Plymouth Rocks, fed same ration as lot No. 3.
[c] Experiment No. II (1919), White Plymouth Rocks, no greens; basal ration containing 10 parts of protein from meat scraps only, instead of meat scraps and soybean meal.
[d] Experiment No. II (1919), White Plymouth Rocks fed same as lot No. 13 with addition of greens.

FECES NITROGEN

A study of the nitrogen of the feces was made to note if any increased utilization or change in the nature of the nitrogen end products could be obtained because of the added compounds. The data from composite samples of the feces taken from the different lots are contained in Table II.

TABLE II.—*Amount and distribution of feces nitrogen*

Lot No.	Average protein consumed per chick in 14 days.	Percentage of total nitrogen.	Percentage of nitrogen soluble in $N/10$ HCl.[a]	Percentage of nitrogen insoluble in $N/10$ HCl.[b]	Percentage of soluble nitrogen in total nitrogen.
	Gm.				
1	58.5	2.23	0.94	1.29	42.1
2	56.78	Lost.	....	....	....
3	68.11	2.20	.91	1.20	41.4
4	67.08	2.02	.94	1.08	46.5
5	73.63	1.77	.89	.88	50.3
6	67.23	1.83	1.15	.68	62.8
7	61.77	1.35	.85	.50	63.0
8	73.78	2.36	1.05	1.31	44.5
9	68.17	2.27	1.02	1.25	44.9
10	68.32	2.18	1.10	1.08	50.5

[a] Urea, ammonia, and amino acid nitrogen. [b] Uric acid and residual nitrogen.

DISCUSSION

Table I gives the results of the different rations outlined, including such factors as green feed, antiseptics, fiber, exercise, and their effect upon and mortality of the chicks. When the gain in weight and mortality of the different lots are considered, a few points stand out prominently and are suggestive as being worthy of further investigation.

The most important of these is the effectiveness of copper sulphate in preventing mortality, probably because of its well-known antiseptic properties. Since an antiseptic seems to be so effective, it adds additional evidence that one of the main causes of mortality of chicks grown in confinement is the intestinal putrefaction so often noticed in the autopsy of chicks. Sprouted oats is thought by some to be effective in lessening mortality, especially when fed for a short time only and when given as a supplement to a somewhat monotonous ration. It is possible that under the conditions of the experiment no benefit was obtained from its use with growing chicks when fed throughout the first 14 weeks of the growing period. Lots No. 11, 12, 13, and 14 noted in Table I include unpublished data obtained in previous experiments which are introduced here as further evidence of the ineffectiveness of greens in preventing chick mortality.

The sulphur received by lot 8 caused a continued looseness of bowels. This did not seem to have any ill effect and may have been of some advantage, since at 8 weeks of age this was one of the best lots. The retarding effect of tobacco was pronounced and resulted in stunting the growth during the first 8 weeks. There was a tendency for the chicks to

recover somewhat by the age of 14 weeks. The chicks in this lot always seemed more wild and nervous than those of any of the other lots.

The use of hydrochloric acid in the drinking water of lot 6 seemed to be of some benefit, inasmuch as the mortality was somewhat less than the average and the growth was consistent throughout the experiment.

Strawboard pulp was supplied to the ration in lots 4 and 5 for the purpose of adding bulk and thereby lessening the danger of impaction of the contents of the small intestine and caeca common when feeding a grain ration. It did not seem to aid in reducing mortality.

Lot 2 was given a litter of oat straw to encourage the chicks to exercise. This did not prove successful in promoting growth, since this lot made the smallest gain of all, nor did it tend to lessen mortality. Lot 1, which was the control lot, received only the basal ration. As shown in Table I, this ration has proved its efficiency in promoting growth and has also proved its inefficiency in checking mortality, especially during the time between the eighth and fourteenth weeks.

It will be noted from Table II that in lot 6 and also in lot 7, which received tobacco, the percentage of nitrogen in the feces was lower than in most of the other lots. Furthermore, it was found that the percentage of nitrogen excreted as uric acid was less, indicating a somewhat greater percentage of utilization of the nitrogen in the feed.

Lactose, which was added to the ration of lot 9 did not seem to aid in lessening mortality or in promoting growth. This may be due to the fact, as stated by Mendel and Mitchell,[1] that birds, unlike mammals, have no sugar-splitting enzyms in the small intestine; hence the sugar fed was not converted into lactic acid to any considerable extent and thus did not aid in checking intestinal putrefaction. This view is further substantiated in the production of the usual amount of uric acid in the feces, since otherwise nitrogen appearing as uric acid would probably have appeared as a soluble ammonium salt, as noted in lot 6 in Table II, where hydrochloric acid was used in the drinking water.

SUMMARY

(1) The tops of sprouted oats seem to be useless as a preventive of digestive disorders or as an aid to the growth of chicks in confinement.

(2) The analysis of the feces indicated that chicks given hydrochloric acid and tobacco powder produced less uric acid in their feces than did the other lots.

(3) Tobacco powder added to the ration of growing chicks prevents their normal growth and causes them to be wild and nervous.

(4) Hydrochloric acid, sulphur, and particularly copper sulphate offer interesting possibilities of success in raising chicks in confinement.

[1] MENDEL, Lafayette B., and MITCHELL, Philip H. CHEMICAL STUDIES ON GROWTH.—I. THE INVERTING ENZYMES OF THE ALIMENTARY TRACT, ESPECIALLY IN THE EMBRYO. In Amer. Jour. Physiol., v. 20, no. 1, p. 81–96. 1907. Bibliography, p. 94–96.

COMPARATIVE UTILIZATION OF THE MINERAL CONSTITUENTS IN THE COTYLEDONS OF BEAN SEEDLINGS GROWN IN SOIL AND IN DISTILLED WATER

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The experiments of Schröder on the distribution of organic and mineral constituents in seedlings of the kidney bean, *Phaseolus vulgaris*, published in 1868 [2] show that, in his fourth stage of germinating, when the second and third joints with the trifoliate leaves have formed, the cotyledons, which have become much reduced in size and more or less shriveled, still retain a considerable proportion of their mineral matter unused. Schröder's analyses show that these shriveled cotyledons retain about nine-tenths of their original calcium, whereas not more than one-fourth of their phosphorus and about two-fifths of their potassium, sodium, and magnesium remain. In regard to the calcium, however, Scröder points out that his determinations appear to be too high and that this result should be verified. In describing Schröder's experiments Pfeffer [3] remarks that—

> complete removal of all of the essential elements is never possible, for even in a starved plant, certain essential structural constituents can not be mobilized or consumed.

In 1915, the author of this paper published some results [4] showing that when the Kentucky Wonder garden bean was grown in distilled water, approximately 86 per cent of the calcium, 50 per cent of the phosphorus, and 40 per cent of the magnesium remained unused in the cotyledons as compared with the amounts found in the normal cotyledons. In this experiment the seedlings had been permitted to grow in distilled water until they became etiolated and died from lack of food. These figures approximate those given by Schröder.

The following experiment was undertaken with the view of comparing the degree of utilization of the total ash and the elements calcium, magnesium, and phosphorus in the cotyledons of bean seedlings grown in distilled water and in garden soil.

In starting the experiment it seemed of primary importance to determine the distribution of the total ash and the elements calcium, magnesium, and phosphorus, which were to be studied, in the separate portions

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[1] The author gratefully acknowledges Dr. A. M. Peter's careful criticism of this manuscript.

[2] SCHRÖDER, Julius. UNTERSUCHUNG ÜBER DIE VERTHEILUNG DES STICKSTOFFS UND DER MINERALBESTANDTHEILE BEI KEIMUNG DER SCHMINKBOHNE. *In* Landw. Vers. Stat., Bd. 10, p. 493-510. 1868.

[3] PFEFFER, W. THE PHYSIOLOGY OF PLANTS . . . ed. 2, transl. and ed. by Alfred J. Ewart. v. 1, p. 584. Oxford, 1900.

[4] BUCKNER, G. Davis. TRANSLOCATION OF MINERAL CONSTITUENTS OF SEEDS AND TUBERS OF CERTAIN PLANTS DURING GROWTH. *In* Jour. Agr. Research, v. 5, no. 11, p. 449-458. 1915.

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of the bean under consideration. Since Schröder used the kidney bean, *Phaseolus vulgaris*, it was decided to use a kidney bean in this experiment, in order to obtain more comparable results. The Kentucky Wonder garden bean is a good example of this type, and, since it is well adapted to this climate, it was chosen.

About 3,000 perfect beans were selected and, after thorough washing, were allowed to soak in distilled water overnight, until the integuments were softened. From 1,000 of these beans the integuments were carefully removed and saved as a separate portion. The cotyledons were then carefully separated, and the embryos were dissected out. The 1,000 embryos and 200 of the cotyledons were separately analyzed, as were 400 integuments and 100 of the whole beans remaining. During these operations, care was taken that the separate portions did not become contaminated with dust or other foreign material. The materials were dried in an electric oven at 100° C. for 24 hours, after which they were weighed, ashed, and the phosphorus was determined by the method of the Association of the Official Agricultural Chemists,[1] while calcium and magnesium were determined according to the method of McCrudden.[2] All the analyses made during the progress of this experiment were similar in every respect. The results are stated in Table I, calculated for 1,000 beans and also as percentage of the moisture-free materials.

In determining the degree of utilization of the elements in question in the cotyledons of beans grown under normal conditions in garden soil, 500 carefully selected beans were planted in a box of garden soil in a room which received the proper amount of sunshine and ventilation. In this room, also, the seedlings in distilled water were grown. Since the room was used only for this purpose, the chance of contamination from dust during the growth of the seedlings was very small. When the bean seedlings had pushed the cotyledons well above the soil, the cotyledons were carefully washed with distilled water and a camel's-hair brush to remove any adhering soil. At all other times the watering was done from below, so that no water touched the cotyledons. As growth advanced, the cotyledons became greatly shriveled and turned brown and finally dropped off upon clean paper so placed as to keep them from falling on the soil. They were then analyzed and calculated according to the method described. The results will be found in Table I.

In that part of the experiment in which the seedlings were to be grown in distilled water, 1,000 beans from a new lot of the same variety (the first lot having been all used) were selected and sterilized by placing them in an atmosphere of formaldehyde gas for four hours, after which

[1] WILEY, H. W., et al. OFFICIAL AND PROVISIONAL METHODS OF ANALYSIS, ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS. AS COMPILED BY THE COMMITTEE ON REVISION OF METHODS. U. S. Dept. Agr. Bur. Chem. Bul. 107(rev.), p. 3. 1908.

[2] McCRUDDEN, F. H. THE QUANTITATIVE SEPARATION OF CALCIUM AND MAGNESIUM IN THE PRESENCE OF PHOSPHATES AND SMALL AMOUNTS OF IRON DEVISED ESPECIALLY FOR THE ANALYSIS OF FOODS, URINE AND FECES. *In* Jour. Biol. Chem., v. 7, no. 2, p. 83-100. 1910.

they were washed with sterile, distilled water and germinated between blotting papers which had been treated with hydrochloric acid and washed free from chlorids with distilled water. The germinating dish was of porcelain and was sterilized by heating at 180° C. for two hours. The beans were allowed to germinate until the radicles were 1 cm. in length, when the integuments were removed and the radicles wrapped in sterile absorbent cotton which had previously been treated with hydrochloric acid and washed free from chlorids with distilled water. This cotton gave practically no ash when incinerated. After the radicles had been wrapped in the absorbent cotton, each bean thus prepared was placed in the mouth of a test tube which had been thoroughly coated inside with paraffin and was held there by applying a few drops of melted paraffin. The test tubes were thoroughly washed with distilled water before the distilled water in which the seedlings grew was placed in them. This water was replaced as rapidly as it was removed by evaporation and by transpiration. The bean seedlings were allowed to grow until they had etiolated and wilted. The seedlings thus formed were uniform in size and development, being about 7 inches in height, with a well-developed root system and having two perfectly formed leaves which were somewhat undersized. The etiolation of the leaves and cessation of growth was taken as a point of maturity at which the cotyledons were removed, in a brown and greatly shriveled condition. They were analyzed as already described, and the results are presented in Table I. Inasmuch as a new lot of Kentucky Wonder beans was used for this part of the experiment, 200 normal cotyledons from beans of this lot were analyzed and the results included in the table for comparison.

TABLE I.—*Analyses of whole beans and the several parts, calculated on the moisture-free material*

Material analyzed.	Dry matter.		Crude ash.		Phosphorus as P_2O_5.		Calcium as CaO.		Magnesium as MgO.	
	Gm.	*Per cent.*	*Gm.*	*Per cent.*	*Gm.*	*Per cent.*	*Gm.*	*Per cent.*	*Gm.*	*Per cent.*
2,000 normal cotyledons	305.200	91.1	13.5300	4.43	4.9600	1.62	0.1989	0.06	0.6034	0.19
1,000 normal embryos	4.005	1.2	.1869	4.67	.0832	2.07	.0059	.15	.0129	.32
1,000 normal integuments	25.796	7.7	1.0467	4.05	.0360	.14	.5100	1.98	.1027	.40
Calculated for 1,000 beans	335.001	100.0	14.7636	4.40	5.0792	1.52	.7148	.21	.7190	.21
1,000 normal whole beans	329.013	100.0	17.8130	5.41	5.0464	1.53	.5914	.18	.8462	.26
2,000 exhausted cotyledons (grown in soil)	23.633	7.7	1.0730	4.54	.3500	1.48	.0372	.16	.0910	.38
2,000 exhausted cotyledons (grown in water)[a]	116.200	40.2	5.4850	4.72	1.9300	1.64	.1344	.12	.1574	.13
2,000 normal cotyledons[a]	278.000	100.0	11.9820	4.31	4.1000	1.47	.1557	.06	.3918	.14

[a] A different lot of Kentucky Wonder beans from those grown in soil.

In Table II will be seen the percentage distribution of phosphorus, calcium, and magnesium in the ash of the separate parts of the beans analyzed. Here we see that the percentages of phosphorus in the normal cotyledons and those exhausted under the given conditions are fairly constant, ranging from 32.62 in the exhausted cotyledons grown in soil to 36.66 in the normal whole cotyledons of the same lot. The percentage of phosphorus in the ash of the exhausted cotyledons of beans grown in distilled water very closely approximates that in the ash of the normal cotyledons of the same lot being 35.18 and 34.22, respectively.

TABLE II.—*Analyses of the ash of beans and of the several parts*

Material analyzed.	Phosphorus as P_2O_5.	Calcium as CaO.	Magnesium as MgO.
	Per cent.	*Per cent.*	*Per cent.*
Normal cotyledons	36.66	1.47	4.46
Embryos	44.50	3.17	6.88
Integuments	3.44	48.73	9.81
Normal whole beans	28.33	3.32	4.75
Exhausted cotyledons (grown in soil)	32.62	3.45	8.48
Exhausted cotyledons (grown in water)[a]	35.18	2.45	2.87
Normal cotyledons[a]	34.22	1.30	3.27

[a] A different lot of Kentucky Wonder beans from those grown in soil.

In Table III will be seen the comparative amounts of dry matter, crude ash, and the elements phosphorus, calcium, and magnesium used by the seedlings grown in distilled water and those grown in garden soil. Here we see that 92.3 per cent of the dry matter, 92 per cent of the total ash, 92.8 per cent of the phosphorus, 81.4 per cent of the calcium, and 84.9 per cent of the magnesium of the cotyledons of beans grown in garden soil was translocated to other parts of the plant before the cotyledons ceased to function as a source of food supply. We see also that only 58.2 per cent of the dry matter, 54.2 per cent of the total ash, 42.9 per cent of the phosphorus, 14.1 per cent of the calcium, and 60 per cent of the magnesium in the cotyledons was utilized by the seedlings grown in distilled water cultures.

TABLE III.—*Comparison of percentages of material translocated from the cotyledons of beans grown in distilled water and in soil*

Material translocated.	In soil.	In distilled water.
Dry matter	92.3	58.2
Crude ash	92.0	54.2
Phosphorus	92.8	52.9
Calcium	81.4	14.1
Magnesium	84.9	60.0

It is readily observed that considerably more of each of these elements was utilized by the seedlings grown in garden soil than by those grown in distilled water. This would seem to indicate either that the distilled water is deleterious to the growth of seedlings grown in it or that something needed in the process of translocation was accessible when the beans were grown in soil but not when they were grown in distilled water.

Distilled water even of the highest purity has been considered toxic to seedlings grown in it, because of the difference between the osmotic pressure within the root cells and that of the distilled water surrounding them. The distilled water used in these experiments was obtained from a Barnstead automatic water still and contained traces of copper and calcium. In this case the toxic effect of the copper, if any could be attributed to it, was counteracted by the calcium, as there was no evidence of the characteristic poisonous effect of copper on the roots.

It is hoped that more light may be thrown on the subject of the utilization of the mineral constituents in the cotyledons by the young plant under varying conditions by experiments now in progress in this laboratory.

SUMMARY

When beans were grown in soil, a notably larger amount of reserve material was translocated from the cotyledons than when they were grown in distilled water.

In both cases, a smaller proportion of calcium was translocated than of phosphorus or magnesium.

SUNFLOWER SILAGE DIGESTION EXPERIMENT WITH CATTLE AND SHEEP[1]

By RAY E. NEIDIG, *Chemist*, ROBERT S. SNYDER, *Associate Chemist*, and C. W. HICKMAN, *Animal Husbandman, Idaho Agricultural Experiment Station*

The object of the experiment reported in this article was to determine the apparent digestibility[2] of silage made from sunflowers when fed to cattle and sheep. Sunflowers have gained a wide reputation as a silage crop in the Pacific Northwest, and much interest is being taken in their growth on lands where corn can not be successfully grown. Sunflowers are a hardier crop than corn, withstanding both drouth and frost to a much greater degree. Another point in favor of sunflowers is the fact that usually a greater tonnage can be secured in the semiarid regions. Many claims are made concerning the high value of sunflower silage for feeding purposes, but little is known at the present time as to its actual value other than numerous practical feeding tests which indicate that sunflowers are a very promising silage crop. Recently, however, the Montana Agricultural Experiment Station has reported on the digestible nutrients in sunflower silage made from a crop of sunflowers harvested when the plants were approximately 5 per cent in bloom. While a full report of the work has not been published, yet a summary of the digestible nutrients found in 100 pounds of silage, together with the same data on mature and immature corn, taken from Henry and Morrison's "Feeds and Feeding" is given in Bulletin 131 as follows:

	Total dry substance.	Crude protein.	Crude fiber and nitrogen-free extract.	Ether extract.	Nutritive ratio.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	
Digestible nutrients in 100 pounds of sunflower silage	21.4	1.24	10.13	0.37	9.8
Digestible nutrients in 100 pounds of mature corn[a]	26.3	1.1	15.00	.70	15.1
Digestible nutrients in 100 pounds silage from immature corn[a]	21.0	1.0	11.40	.40	12.3

[a] HENRY, W. A., and MORRISON, F. B. FEEDS AND FEEDING . . . ed. 17, x, 691 p. Madison, Wis., 1917.

From the digestible nutrients found in the sunflower silage and from the practical feeding experiments carried on by the Montana Agricultural Experiment Station, with dairy and beef cattle, ewes, and brood sows they conclude that sunflowers are a valuable silage crop.

[1] Published by the permission of Director E. J. Iddings, Idaho Agricultural Experiment Station, as a joint project of the Department of Agricultural Chemistry and Animal Husbandry.

[2] Throughout this article the coefficients of digestibility refer to the coefficients of apparent digestibility—that is, the difference in the weights of the nutrients of the silage fed and in the feces expressed in percentages of the total nutrients eaten.

During the past two years similar work has been carried out at the Idaho Agricultural Experiment Station, a part of which is reported in this article on the digestion experiments with cattle and sheep. The silage used was made from a crop of sunflowers harvested when about 50 per cent of the sunflowers were in bloom, but when only a few seeds were in the dough stage. The plan of the work and the data secured follow.

PLAN OF EXPERIMENT

Three registered Shorthorn cows, No. 5, 6, and 7, were used in the experiment. These were the only cows available at the time the experiment was conducted. Their ages varied, cow No. 5 being 3 years old, cow No. 6 being 10 years old, and cow No. 7 being 5 years old. These cows were kept in specially prepared stalls, which were arranged so that it was possible to obtain an exact record of all silage eaten, water consumed, all silage rejected, and all feces voided. No record was kept of the urine, either as to the amount voided or as to its chemical analysis.

Three yearling wethers, all pure-bred Shropshires, were placed in specially constructed pens which facilitated the securing of records on the amount of silage fed, silage eaten, water consumed, and feces voided.

The preliminary feeding period extended over a period of 10 days, during which time the animals were given an opportunity to accustom themselves to their surroundings, and also to ascertain the maximum amount of silage that they would consume daily. It was found that 50 pounds was the proper amount to feed the cows, while 2 pounds were sufficient for the daily sheep ration. The cows and sheep were fed one-half the full ration both morning and evening. When the animals appeared to be normal in every way a few days were allowed to elapse and then the final digestion period of seven days' duration was begun. During this period samples of the silage fed, silage rejected, and feces voided were collected daily and composited. Daily records of the amounts of silage fed, silage rejected, and feces voided were secured, together with the daily weights of the animals. Chemical analyses were made of all composite samples. The results are given on both the wet and dry basis in Table I.

Table II contains the amount of silage fed to cows and sheep, the water consumed, feces voided, silage rejected (called orts), and the daily weight of each individual cow and sheep. Table III contains the total weight of silage fed, the total nutrients contained in the silage eaten, and the feces voided. The amount of nutrients and the percentage digested are also given for each animal. In calculating the nutrients eaten, the total nutrients contained in the silage rejected were subtracted from the total nutrients contained in the silage fed. Hence the figures represent the actual amount of dry substance and nutrients eaten. The results are all expressed on the moisture-free basis.

TABLE I.—*Chemical composition of silage, orts, and feces*

	Moisture.	Dry substance.	Crude protein.		Crude fiber.		Ether extract.		Nitrogen-free extract.		Ash.	
			Wet basis.	Dry basis.	Wet basis.	Dry basis.	Wet basis.	Dry basis.	Wet basis.	Dry basis.	Wet basis.	Dry basis.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Silage fed	78.79	21.21	2.03	9.59	6.30	29.72	1.23	5.82	9.56	45.03	2.09	9.84
Orts rejected:												
Cow 5	69.08	30.92	1.47	4.77	15.8	51.1	.43	1.40	11.41	36.88	1.81	5.85
Cow 6	73.12	26.88	1.37	5.11	12.67	47.15	.41	1.54	10.40	38.66	2.03	7.54
Cow 7	......	......	......	......	......	......	......	......	......	......	......	......
Sheep 2	......	......	......	......	......	......	......	......	......	......	......	......
Sheep 3	72.58	27.42	1.38	5.04	13.41	48.9	.43	1.58	10.21	37.22	1.99	7.26
Sheep 8	69.9	30.1	1.55	5.14	13.94	46.3	.57	1.91	11.89	39.51	2.15	7.14
Feces voided:												
Cow 5	77.64	22.36	2.20	9.85	8.73	39.04	.62	2.93	7.44	33.10	3.37	15.08
Cow 6	78.94	21.06	2.31	10.99	7.95	37.75	.67	3.19	6.95	32.95	3.18	15.12
Cow 7	75.46	24.54	2.58	10.51	9.21	37.53	.85	3.46	8.26	33.66	3.64	14.84
Sheep 2	52.09	47.91	5.12	10.69	17.88	37.33	1.49	3.11	16.00	33.38	7.42	15.49
Sheep 3	56.46	43.54	4.34	9.96	16.90	38.81	1.47	3.37	14.82	34.05	6.01	13.81
Sheep 7	56.27	43.73	5.19	11.87	16.87	38.58	1.36	3.11	13.69	31.31	6.62	15.13

TABLE II.—*Feed and water consumed, feces voided, orts rejected, and daily weight of cows and sheep*

Date.	Silage fed to cows.	Water consumed by cows.			Feces voided by cows.			Orts rejected by cows.			Daily weight of cows.		
		No. 5.	No. 6.	No. 7.	No. 5.	No. 6.	No. 7.	No. 5.	No. 6.	No. 7.	No. 5.	No. 6.	No. 7.
	Kgm.	*Kgm.*	*Kgm.*	*Kgm.*	*Kgm.*	*Kgm.*	*Kgm.*	*Kgm.*	*Kgm.*	*Kgm.*	*Pounds.*	*Pounds.*	*Pounds.*
Apr. 5	22.68				8.390	6.580	7.600	0.455	0.398		1,050	1,170	1,170
6	22.68				10.660	8.735	11.455	.195	.550		1,050	1,170	1,170
7	22.68				10.000	9.195	8.160	.306	.295		1,040	1,188	1,173
8	22.68		14.7		10.445	10.325	11.000	.248	.488		1,035	1,180	1,170
9	22.68	6.8			10.325	11.565	9.072	.263	.733		1,040	1,175	1,173
10	22.68				10.660	13.610	10.550	.244	.574		1,033	1,195	1,165
11	22.68				11.565	11.680	11.000	.156	.486		1,045	1,168	1,155
Weight at end of period											1,033	1,153	1,150

Date.	Silage fed to sheep.	Water consumed by sheep.			Feces voided by sheep.			Orts rejected by sheep.			Daily weight of sheep.		
		No. 2.	No. 3.	No. 8.	No. 2.	No. 3.	No. 8.	No. 2.	No. 3.	No. 8.	No. 2.	No. 3.	No. 8.
	Kgm.	*Kgm.*	*Kgm.*	*Kgm.*	*Kgm.*	*Kgm.*	*Kgm.*	*Kgm.*	*Kgm.*	*Kgm.*	*Pounds.*	*Pounds.*	*Pounds.*
Apr. 5	1.814				0.383	0.462	0.355		0.132		123	131	112
6	1.814				.332	.427	.201				122	131	110
7	1.814				.339	.413	.251		.049	0.120	122	131	110
8	1.814				.273	.376	.305				122	130	110
9	1.814	0.342	0.342		.357	.427	.261		.045		122	129	110
10	1.814				.370	.427	.303				121	130	111
11	1.814				.333	.420	.284				122	128	111
Weight at end of period											122	127	110

Table IV gives the apparent coefficients of digestibility for each animal, together with the average coefficients for the three cows and sheep, respectively.

Table V gives the pounds of digestible dry matter and pounds of digestible nutrients in 100 pounds of sunflower silage. The individual nutritive ratio for each animal is given, together with the average nutritive ratio for the cows and sheep.

TABLE III.—*Total weights of sunflower silage, feces, and water for the 7-day period*

[Results expressed in kilograms on moisture-free basis]

	Dry substance.	Crude protein.	Crude fiber.	Ether extract.	Nitrogen-free extract.	Ash.
COW NO. 5						
Silage fed minus orts	33. 096	3. 203	9. 714	1. 952	14. 848	3. 279
Feces voided	16. 109	1. 586	6. 293	. 472	6. 206	2. 430
Amount digested	16. 987	1. 617	3. 421	1. 480	8. 642	. 849
Percentage digested	51. 300	50. 500	35. 200	75. 800	58. 200	25. 900
COW NO. 6						
Silage fed minus orts	32. 731	3. 181	9. 564	1. 945	14. 799	3. 242
Feces voided	15. 098	1. 660	5. 700	. 482	7. 511	2. 282
Amount digested	17. 633	1. 521	3. 864	1. 463	7. 288	. 960
Percentage digested	53. 900	47. 800	40. 400	75. 200	49. 200	29. 600
COW NO. 7						
Silage fed minus orts	33. 673	3. 229	10. 008	1. 960	15. 163	3. 313
Feces voided	16. 893	1. 776	6. 342	. 584	5. 860	2. 511
Amount digested	16. 780	1. 453	3. 666	1. 376	9. 303	. 802
Percentage digested	49. 800	45. 000	36. 600	70. 200	61. 400	24. 200
SHEEP NO. 2						
Silage fed minus orts	2. 694	0. 258	0. 801	0. 157	1. 213	0. 265
Feces voided	1. 144	. 122	. 427	. 036	. 382	. 177
Amount digested	1. 550	. 136	. 374	. 121	. 831	. 088
Percentage digested	57. 500	52. 700	46. 700	77. 100	68. 500	33. 200
SHEEP NO. 3						
Silage fed minus orts	2. 634	0. 255	0. 772	0. 156	1. 190	0. 261
Feces voided	1. 286	. 127	. 499	. 043	. 439	. 178
Amount digested	1. 348	. 128	. 273	. 113	. 751	. 083
Percentage digested	51. 200	50. 200	35. 400	72. 400	63. 100	31. 800
SHEEP NO. 8						
Silage fed minus orts	2. 664	0. 256	0. 787	0. 156	1. 202	0. 263
Feces voided	. 858	. 102	. 331	. 027	. 268	. 130
Amount digested	1. 806	. 154	. 456	. 129	. 934	. 133
Percentage digested	67. 800	60. 200	57. 900	82. 700	77. 700	50. 600

TABLE IV.—*Coefficients of digestibility for cows and sheep*

[Expressed in percentages]

	Dry substance.	Crude protein.	Crude fiber.	Ether extract.	Nitrogen-free extract.	Ash.
Cow No.—						
5	51.3	50.5	35.2	75.8	58.2	25.9
6	53.9	47.8	40.4	75.2	49.2	29.6
7	49.8	45.0	36.6	70.2	61.4	24.2
Average for cows	51.7	47.8	37.4	73.7	56.3	26.6
Sheep No.—						
2	57.5	52.7	46.7	77.1	68.5	33.2
3	51.2	50.2	35.4	72.4	63.1	31.8
8	67.8	60.2	57.9	82.7	77.7	50.6
Average for sheep	58.8	54.4	46.7	77.4	69.8	38.5

TABLE V.—*Nutrients digested by cows and sheep in each 100 pounds sunflower silage*

[Estimated on wet basis]

	Dry substance.	Crude protein.	Crude fiber.	Ether extract.	Nitrogen-free extract.	Nutritive ratio.
Cow No.—	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds*	
5	10.9	1.03	2.22	0.93	5.56	9.6
6	11.45	.97	2.55	.93	4.71	9.6
7	10.56	.91	2.31	.86	5.87	11.1
Average for cows	10.97	.97	2.34	.91	5.38	10.1
Sheep No.—						
2	12.2	1.07	2.94	0.95	6.55	10.9
3	10.86	1.02	2.23	.89	6.03	10.1
8	14.4	1.22	3.65	1.02	7.43	10.9
Average for sheep	12.49	1.1	2.94	.95	6.68	10.6

INDIVIDUALITY OF COWS AND SHEEP AS TO THE AMOUNT OF SILAGE DIGESTED

An inspection of the tables shows that the three cows and three sheep all varied considerably in the amount of dry substances digested. In general, the same ratio of dry substance digested and nutrients absorbed existed. The sheep showed a much larger variation in total dry matter digested than was noted with the cows. The results of this one digestion period indicate that there exists an individuality among animals as to the thoroughness with which they digest their feed. This view is supported by the recent work of Grindley [1] and his associates on diges-

[1] GRINDLEY, H. S., CARMICHAEL, W. J., and NEWLON, C. E. DIGESTION EXPERIMENTS WITH PIGS . . . Ill. Agr. Exp. Sta. Bul. 200, p. 55-94, 4 fig. 1917.

tion experiments with pigs, in which they found individual differences in pigs of the same age and species in the amount of feed digested which prevailed throughout 40 digestion periods.

It is readily seen that to secure an average digestion coefficient with any class of animals, a considerable number should be employed, which would mitigate the factor of errors introduced by individuality of the animals. If, however, a considerable number of animals are employed, the work becomes very voluminous and necessitates a large number of men to carry the experiment to completion. While these individual differences are not very great, it is thought that a sufficiently close digestive coefficient value can be obtained by using a smaller number of animals. In this work it is believed that the average coefficient obtained for the cows and sheep closely approximate the true digestive coefficient. A comparison of the analysis of the sunflower silage fed at this station and that fed at Montana, together with the digestible nutrients contained in each silage, follows.

TABLE VI.—*Comparison of sunflower silage fed at Idaho and Montana Agricultural Experiment Stations*

	Dry substance.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Ash.	Crude fiber and nitrogen-free extract.	Nutritive ratio.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	
Sunflower silage, Montana	21.4	2.1	6.8	10.4	0.5	1.6	....	....
Sunflower silage, Idaho	21.21	2.03	6.3	9.56	1.23	2.09	....	....
Digestible nutrients in 100 pounds silage, Montana	21.4	1.24	....	....	.37	....	10.13	9.8
Digestible nutrients in 100 pounds silage, Idaho cows	21.21	.97	....	....	.91	....	7.72	10.1
Digestible nutrients in 100 pounds silage, Idaho sheep	21.21	1.10	....	....	.95	....	9.61	10.6

It is seen that a slight difference exists between the digestive nutrients found by Montana and those obtained by us, but the difference is small. No data are available as to the kind of animals used by Montana, hence no comments can be made. The nutritive ratio found by Montana and by Idaho is quite similar. Some of the difference is no doubt due to the different stages of maturity of the sunflowers. Montana silage was made from sunflowers cut when 5 per cent were in bloom, while Idaho silage represents a crop cut when 50 per cent were in bloom.

Additional studies are needed to determine the best time to cut sunflowers in order to secure the maximum food value.

When the digestion coefficients of sunflower silage obtained from cattle and sheep are compared with the coefficients of immature corn given in the early part of this paper, it is seen that for protein the cows utilizep practically the same amount from sunflower silage that they utilized from immature corn. With sheep, there is slightly more digestible protein

in immature corn silage. When sunflower silage is compared with mature corn, it is seen that the cows utilize slightly less protein from sunflowers than from corn silage, whereas sheep utilize similar amounts.

SUMMARY

(1) Analysis of sunflower silage fed at the Idaho Agricultural Experiment Station indicated that it compared very favorably with corn silage.

(2) The digestible nutrients contained in sunflowers compare favorably with the digestible nutrients in mature and immature corn.

(3) The nutritive ratio is somewhat narrower in sunflower silage than in mature or immature corn silage.

(4) Sheep utilized slightly more nutrients in sunflower silage than did cows under the conditions of this experiment.

(5) Where both corn and sunflowers can be grown, the selection of a silage crop should depend upon comparative tonnage per acre and cost of harvesting.

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